CALTRANS

Upstate California Regional Intelligent Transportation System (ITS) Master Plan

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Upstate CA
Regional ITS Plan

NORTH STATE SUPER REGION

Caltrans

FINAL

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Regional Intelligent Transportation System Master Plan – Upstate California

Draft Plan

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EXECUTIVE SUMMARY

Introduction

Existing and emerging technology continues to affect the way that operators manage and travelers interact with the transportation network. Connected and Automated Vehicles bring significant promise, especially when combined with some of the new transportation business models that have emerged as part of the Sharing Economy. Transportation Network Companies (TNCs), car share providers, and other alternatives are combining to deliver on the eventual promise of Mobility-as-a-Service (MaaS). When these business models and technology advances come together, the new mobility options will be truly disruptive.

The Upstate California Regional Intelligent Transportation System Master Plan (Regional ITS Plan) is intended to be a roadmap for the application and integration of ITS strategies into the region's transportation system over the next ten years. The plan was initiated by California Department of Transportation (Caltrans) District 1 and expanded to cover the North State Super Region (Super Region). The Super Region encompasses the 16 counties that make up the area north of Sacramento and the San Francisco Bay Area and covers all or part of three Caltrans districts. The term Upstate California is used for the title of this document to define the geographic location and brand the project.

The Regional ITS Plan was developed through a cooperative effort by the California Department of Transportation (Caltrans) and the Super Region's transportation planning and operating agencies. This document is meant to create a guiding force to improve safety, mobility, and accessibility by staying on the forefront of change and taking advantage of improved efficiencies to management, maintenance, and traveler interfaces offered by changing technology and ITS solutions.

Context

While this plan is focused on ITS, it is intended to support the overall regional transportation vision, goals, and objectives stated in the California Transportation Plan and various county-wide and corridor-level transportation plans. Common themes expressed in these plans are those of safety, efficiency, and reliability of the transportation system. This plan focuses on how ITS will support those higher level transportation goals and objectives.

It is important to recognize that ITS planning and concepts are not new to the Super Region. While this is the first such effort to encompass the entire Super Region, a number of ITS strategic planning and architecture studies, covering various parts of the region, have been undertaken previously. In addition, a number of other technology-related initiatives are being undertaken on a statewide level by Caltrans. For example, Caltrans is committed to optimizing multimodal transportation system performance through an integrated Transportation Systems Management and Operations (TSMO) approach. TSMO encompasses well-known strategies such as incident management, traffic signal timing, ramp metering, and road weather management. Caltrans has also developed a Traffic Signal Operations Business Plan that identifies the steps "to advance management practices and operational strategies that promote the safe and efficient use of the arterial roadway capacity to reduce congestion." This Regional ITS Plan serves as an opportunity to further promote concepts of these initiatives.

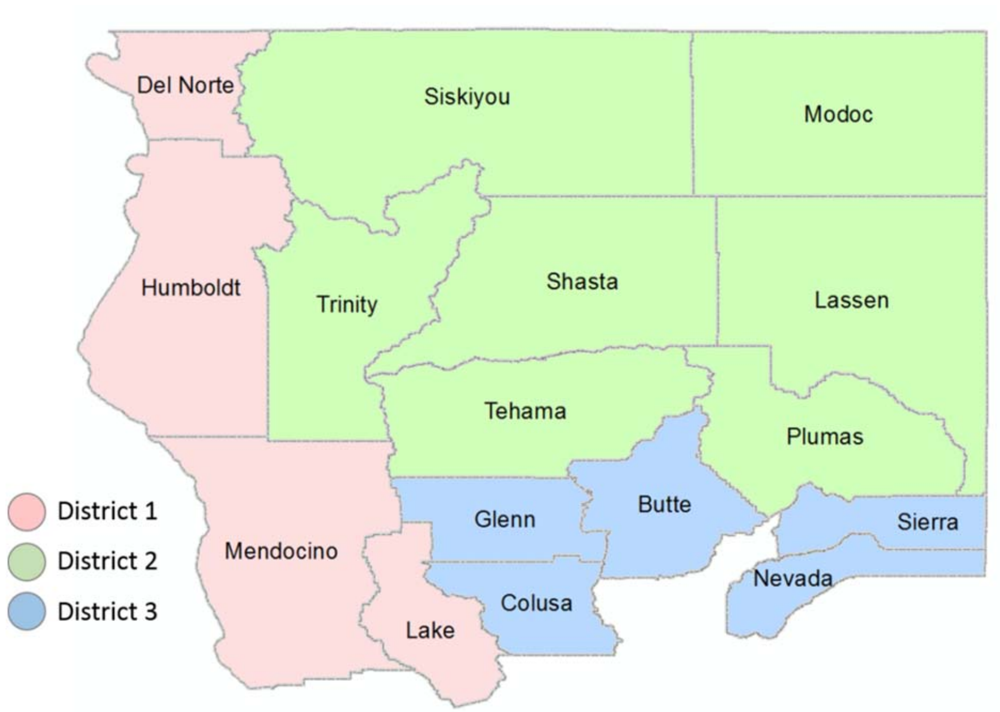
This plan does not establish priorities or schedules for the specific ITS elements and locations that are proposed. It is assumed that the ITS elements presented in this plan will most likely not be implemented as stand-alone projects, but rather integrated into larger transportation improvement projects. As these improvement projects are elevated to near-term programs, the ITS elements listed here will be included in the project design, in a manner consistent with the applicable ITS architecture (see Section 5.3 for further discussion).

Setting

The Super Region, as illustrated below, is a geographically diverse area that includes the low-lying coastal area, the coastal mountain ranges, the northern Sacramento Valley, and the Cascade/Sierra Nevada mountain ranges. The climate is similarly diverse with a variety of temperatures and precipitation patterns and types.

At the same time, the region is very similar in that it is largely rural in nature. While it represents over a quarter of the State of California by area, it contains less than 3% of the population. The largest urban centers in the Super Region, Redding and Chico, have just over 90,000 each in population, with the next largest of Eureka having a population of 27,000. Numerous unincorporated communities also dot the region. As further evidence of its rural nature, the region contains 15% of the state's centerline mile of public roadways, but contributes only about 4% of the state's vehicle miles travelled (VMT).

While many of the more commonly used ITS strategies and tactics tend to be most applicable to urbanized areas or semi-rural corridors that have very high levels of transportation activity, very little of the Super Region falls into either of these categories. As such, the strategies and tactics contained in this Regional ITS Plan are intended to reflect the different characteristics between the rural and urban environments. These differences can include longer trip lengths, a lack of alternative routes, and a higher percentage of travelers unfamiliar with the area. In addition, the larger distances, rugged terrain, and remoteness in rural areas can make maintenance, providing power, and communication more challenging.



Also critical to the development of the Regional ITS Plan was an understanding of the region's transportation-related problems, needs, and challenges. The importance of this lies in the principle that ITS strategies and projects should be designed specifically to address these challenges. Based on stakeholder input, the following needs and challenges were identified:

- Safety
- Traveler Information
- Emergency Response and Incident Management
- Street and Highway System Maintenance
- Congestion/Roadway Operations
- Transit Efficiency and Effectiveness
- Transportation Planning Data

These needs and challenges are not necessarily presented in order of priority. Furthermore, the level of priority for these challenges often varies by District, county, and subarea within individual counties.

The region has already deployed several ITS applications, which form the building blocks for an integrated regional Intelligent Transportation System. Most of these applications have been implemented by Caltrans, and the primary applications include District Traffic Management Centers, closed circuit television cameras, traffic detection, changeable message signs, highway advisory radio, road weather information systems, and web and app-based traveler information. Additionally, some transit providers have also implemented ITS applications, mainly focused on traveler information systems and advanced transit fare payment.

Regional ITS Goals

The vision for ITS in Upstate CA is to:

Provide technology, systems, and equipment to support the transportation goals of Caltrans, the 16 counties, and the local communities within the Upstate California Super Region in a manner that is collaborative and performance-based, thereby maximizing the safety, efficiency, reliability, and overall performance of the transportation system.

We have defined one overarching goal for ITS as:

Improve safety and efficiency of travel for all modes on the highway network

In support of the vision and overall goal, the following nine specific goals were identified:

- Provide accurate, timely, and reliable traveler information
- Improve highway incident management
- Improve emergency management
- Improve safety on the roadway system
- Improve highway freight operations
- Improve roadway maintenance
- Improve transit operations
- Enhance transportation planning
- Reduce variability of delays at intersections

An important element of the ITS planning process is understanding the relationship between the stated goals and objectives of the region and the ITS strategies and tactics being deployed. This relationship was developed by defining each goal with a set of objectives and then identifying the strategies and tactics that support each objective.

Recommended 10-Year Plan

As presented in this document, there is a long list of potential ITS tactics applicable to the Super Region. However, not all of the tactics applicable to the Super Region may be actively pursued by the region's public agencies in the near-term. As part of the Regional ITS Plan development process, input was solicited from stakeholders to identify those tactics and ITS applications that best address the region's needs and goals. The resulting set of tactics, referred to as "Tier 1" tactics, represent the priorities for ITS deployment by public agencies within the Super Region over the 10-year timeframe of this plan.

The Tier 1 tactics include:

- CCTV Cameras
- Roadway Weather Information Systems Stations
- 3rd Party Travel Info Resources
- Advanced Signal Operation and Infrastructure
- Automated Safety Warning Systems
- Emergency Vehicle Pre-Emption
- Changeable Message Signs
- Highway Advisory Radio
- Maintenance Fleet Tracking/Automated Vehicle Location System
- Transit Fleet Automated Vehicle Location System
- Advanced Fare Payment System
- Satellite TMC
- Communications Upgrades
- Regional Architecture
- Incident response procedures and protocols
- Emergency response procedures and protocols

These tactics are generally applicable within each of the counties and Districts in the Super Region. However, specifics of their deployment will be customized to suit the conditions within each county and District.

While "Tier 1" tactics represent those of a higher priority and are expected to be actively pursued for implementation within the timeframe of this plan, there are many others that may apply to the Super Region. These "Tier 2" tactics include those that currently have a limited need, are lacking in specific proposals, or would more likely be implemented by entities outside of the region such as Caltrans HQ or the private sector.

Implementation

This Regional ITS Plan also identifies a number of supporting policies and procedures that are crucial to advancing ITS in the Super Region. Among these is the need for Caltrans, through the three District offices, to take an active leadership role in promoting and coordinating of ITS activities, and includes providing technical and institutional support to other agencies. As part of this, Caltrans should take the lead in facilitating inter-agency coordination and integration to ensure that all proposed projects and ITS deployments are in conformance with applicable ITS

Architecture requirements. Caltrans should also take responsibility for maintaining and updating the Regional ITS Plan. In this regard, it is recommended that in the near-term this plan be broken into separate plans for each District. Creating separate plans will ease the update process and allow for more flexibility in modifying elements of the plan. This approach recognizes that while coordination and communication between Districts does occur, the level of ITS integration between Districts is very limited at this time. However, this should be re-visited in the future as greater integration of systems occurs.

Another key policy is that of facilitating ITS deployment by incorporating ITS elements into all highway and roadway improvement projects. Throughout planning and design process, ITS elements that can be usefully deployed in conjunction with the improvements should be identified and incorporated. At the same time, it is also important to recognize that for more complex ITS elements and projects, it may be necessary to define a specific project and seek separate funding.

The Regional ITS Plan is intended to help the Super Region move towards the goals of interoperability and integration that are the primary concepts behind federal ITS requirements and guidelines. This plan represents one element in meeting these requirements. It also provides guidance that will ensure that future projects conform with ITS Architecture requirements.

1 INTRODUCTION

As we head into the future, the application of technology to our transportation networks will become ever more important. Emerging trends and technology will radically affect the way that operators manage and travelers interact with the transportation network. Connected and Automated Vehicles bring significant promise, especially when combined with some of the new transportation business models that have emerged as part of the Sharing Economy. Transportation Network Companies (TNCs), car share providers, and other alternatives are combining to deliver on the eventual promise of Mobility-as-a-Service (MaaS). When these business models and technology advances come together, the new mobility options will be truly disruptive. Even in the short term, long before this shift occurs, the proliferation of intelligent transportation systems (ITS) will bring undeniable change and must be anticipated.

The Upstate California Regional ITS Master Plan (Regional ITS Plan) was initiated by California Department of Transportation (Caltrans) District 1 and expanded to cover the North State Super Region (Super Region). The Super Region encompasses the 16 counties that make up the area north of Sacramento and the San Francisco Bay Area. In an effort to identify the geographic location of the plan and provide a shorter brand name, the term Upstate California is used for the title of this document. The goal of this document is to create a guiding force to improve safety, mobility, and accessibility for all by staying on the forefront of change and ensure that the Super Region is not left behind.

1.1 Purpose

As illustrated in Figure 1, the Super Region is defined as encompassing the sixteen (16) northernmost counties in California: Butte County, Colusa County, Del Norte County, Glenn County, Humboldt County, Lake County, Lassen County, Mendocino County, Modoc County, Nevada County, Plumas County, Shasta County, Sierra County, Siskiyou County, Tehama County, and Trinity County. The region also covers all or part of three Caltrans Districts.

The Regional ITS Plan is intended to be a roadmap for the application and integration of ITS strategies into the region's transportation system over the next ten years.

The Regional ITS Master Plan is an important tool that will be used by:

- Transportation agencies, to recognize and plan for transportation integration opportunities, not only within each Caltrans District, but within the whole Super Region and on a statewide basis.
- Caltrans, to better reflect integration opportunities and operational needs into the transportation planning process, and
- Other organizations (private sector) and individuals that use the transportation system in the Region.

The expectation is to achieve a shared vision of how each agency's systems will work together as technology continues to develop, sharing information and resources to provide a safer, more efficient, and more effective transportation system for travelers utilizing the transportation system network. The Regional ITS Plan addresses existing ITS subsystems, as well as those planned for development over the next ten years.

Upstate CA
Regional ITS Plan

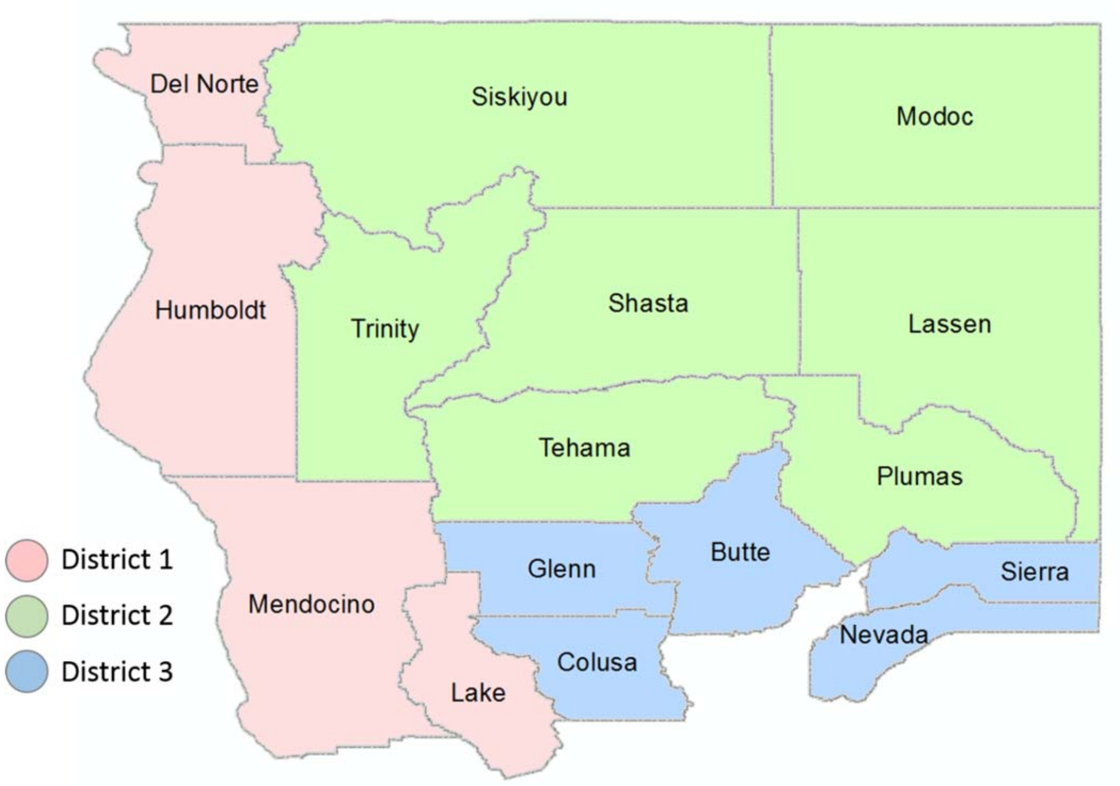


Figure 1 Map of Upstate Region

The Regional ITS Master Plan has been developed through a cooperative effort involving Caltrans, the Federal Highway Administration (FHWA), and the transportation planning and operating agencies within each of the counties in the region. The key is to plan for technology deployment in a cooperative environment among stakeholders to promote interoperability of technology solutions across geographic and institutional boundaries and the efficiency of project deployment and stakeholder resources.

Interoperability and integration are the primary concepts behind federal ITS requirements and guidelines. This Plan is intended help the Super Region move towards these objectives. It represents one element in meeting ITS Architecture requirements, and provides guidance that will help agencies meet the conformance requirements for individual projects.

This plan is viewed as a living document that will require regular updates by Caltrans staff to ensure that it maintains an accurate representation of the Region's existing and planned ITS elements. The Plan is divided among Caltrans Districts 1, 2, and 3 to allow updates to occur on an individual basis, but also combined together to encourage coordination.

1.2 Context

While this plan is focused on ITS, it is intended to support the overall regional transportation vision, goals, and objectives as stated in the California Transportation Plan (CTP) 2040[1] and various county-wide and corridor-level transportation plans. The goals and objectives stated in those plans are typically applicable to all modes and all elements of the transportation system. Common themes expressed in these plans are those of safety, efficiency, and reliability of the transportation system. This plan will be limited to how ITS will support those higher level transportation goals and objectives. The relationship of the Regional ITS Plan within the broader transportation planning process is reflected in Figure 2.

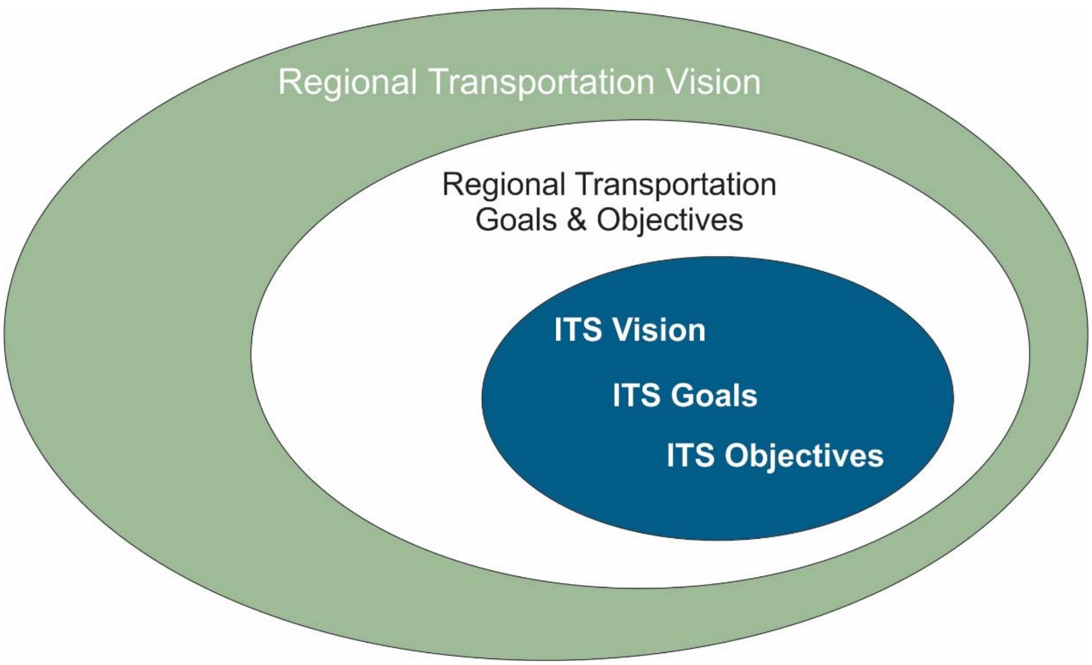


Figure 2 Context of the ITS plan

In addition to these various transportation plans, it is important to recognize a number of other technology-related initiatives being undertaken on a statewide level by Caltrans. For example, Caltrans is committed to optimizing multimodal transportation system performance through an integrated Transportation Systems Management and Operations (TSMO) approach. As defined by FHWA, TSMO is a set of integrated strategies to optimize the performance of existing infrastructure, and includes well-known strategies such as incident management, traffic signal timing, ramp metering, and road weather management. While individual agencies have successfully applied many TSMO strategies, a key element of the TSMO philosophy is the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and

[1] www.californiatransportationplan2040.org

projects. This Regional ITS Plan serves as an opportunity to further promote concepts of multimodal and inter-agency coordination and integration.

Caltrans has also developed a Traffic Signal Operations Business Plan[2] that identifies the steps to achieve the 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." Strategies include those related to signal timing reviews, performance measurement, bicycle and vehicle detection, transit signal priority, CCTV cameras, and signal-to-center communication.

In 2014, Caltrans deployed the Traffic Signal Management and Surveillance System (TSMSS) across California. This system allows for remote communication with signalized intersections. 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. A related goal within the Business Plan is for Districts to have at least 75% of their traffic signal inventory connected in to TSMSS by December 2020.

It should also be noted that this is the not the first ITS planning effort for the region. While it is the first such effort to encompass the entire Super Region, a number of ITS strategic planning and architecture studies, covering various parts of the region, have been undertaken previously. The current plan seeks to build on these efforts, incorporating new and emerging technology while also emphasizing regional integration and cooperation among stakeholders. Areas covered by prior ITS strategic plans and ITS Architectures[3] are illustrated in Figure 3.

[2] Source: http://www.dot.ca.gov/trafficops/tm/docs/Traffic-Signal-Business-Plan-2015.pdf

[3] Source: http://www.dot.ca.gov/drmt/docs/its/ca,map.of.its.plan.pdf

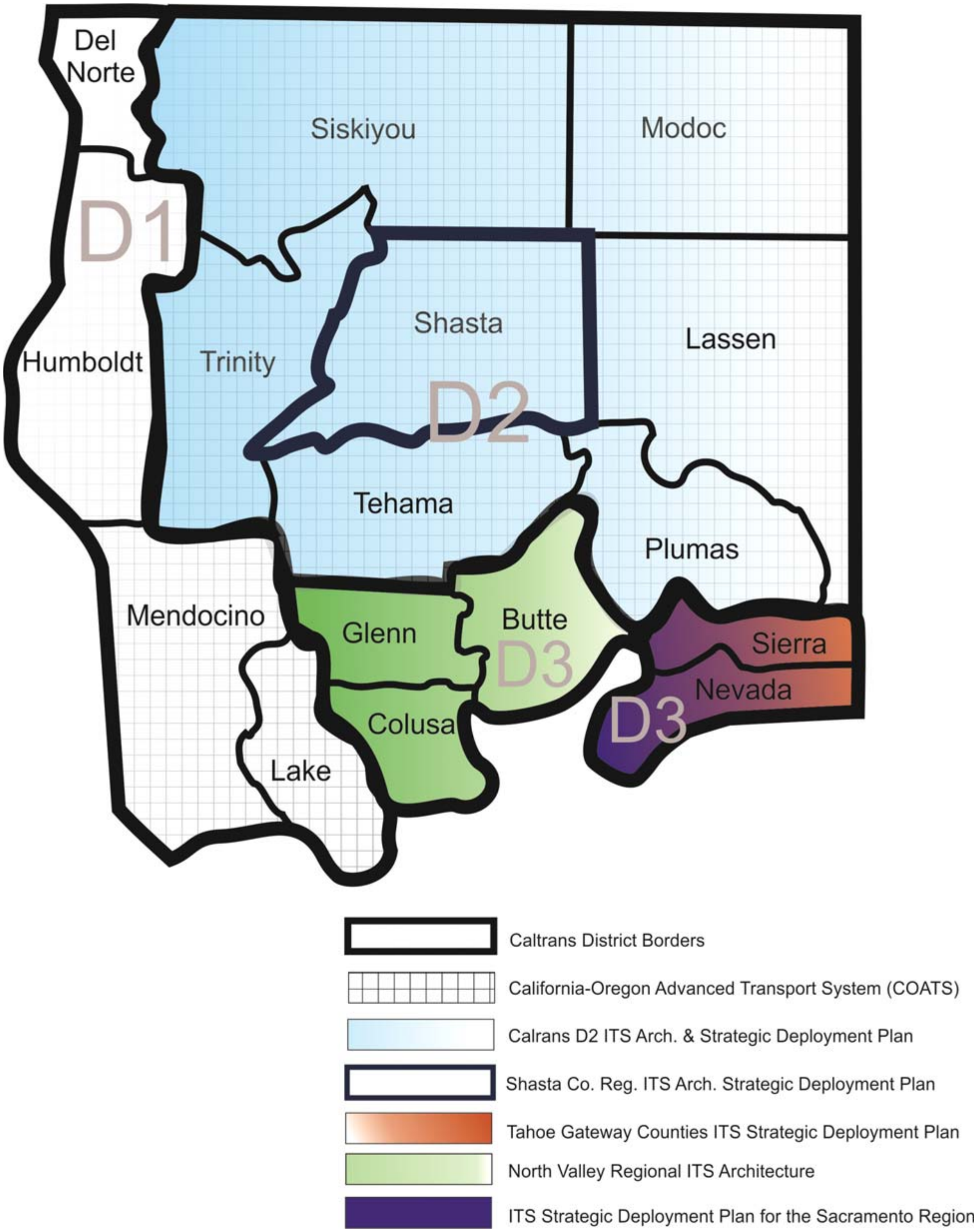


Figure 3 Prior ITS Plans and Architectures

2 WHERE ARE WE NOW?

To determine what ITS applications are appropriate for the Super Region, it is first necessary to understand the environment into which they must fit. This chapter provides an overview of the Super Region's general characteristics and transportation system. It also includes a summary of the various ITS applications already implemented by both Caltrans and local agencies.

2.1 General Description

As previously noted, the Super Region is defined as encompassing the sixteen northernmost counties in California (see Figure 1). It is a geographically diverse area that includes the low-lying coastal area, the coastal mountain ranges, the northern Sacramento Valley, and the Cascade/Sierra Nevada mountain ranges. The climate is similarly diverse. Along the coast the climate is temperate, commonly with cool temperatures, high precipitation, and fog cover. The climate becomes markedly dryer within the inland valleys where average summer temperatures can reach into the high 90s. During the winter months, the mountain passes are subject to severe winter weather (ice, snow, heavy rains).

This area is markedly rural; the 16 counties in the Super Region account for over a quarter of the State of California by area, but less than 3% by population. The region includes a number of incorporated cities which range from small farming communities to regional urban centers. At just over 90,000 each in population, Redding and Chico represent the largest urban centers in the region. The next largest is Eureka, at about 27,000. Numerous unincorporated communities also dot the region.

The region contains 15% of the state's centerline mile of public roadways, but contributes only about 4% of the state's vehicle miles travelled (VMT)[4]. This is reflective of the low population, large geographic area, and extensive road system for moving goods and people from the West Coast to Nevada and from Southern California to Oregon and Washington.

Characteristics that distinguish the rural traveler and setting from their urban counterparts include:

- Trip lengths are greater than in urban areas.
- There is little recurrent congestion; delay most often caused by non-recurring events such as incidents and severe weather.
- Alternative routes may not be available or are few in number.
- Tourists and other unfamiliar travelers represent a large proportion of rural road users.
- Many of the roadway miles are owned and operated by Caltrans and county governments.
- Due to distance and remoteness, rural roadways can be more difficult to maintain, which means that severe and rapidly changing weather conditions are more problematic.
- Remote regions and rugged terrain present additional challenges, such as those related to limited power and communications infrastructure.

[4] California Public Road Data 2015, http://www.dot.ca.gov/hq/tsip/hpms/datalibrary.php

2.2 Transportation Network

I-5 and I-80 are the two interstates serving the region. I-5 effectively bisects the region and provides north-south connectivity. I-80 provides east-west connectivity over the Sierra Nevadas, touching upon the southern edge of the region. The Interstate highways are the backbone of the State transportation system and are critical to interregional/international travel and commerce. I-5 is a major north-south freight corridor for goods movement between Canada and Mexico, while I-80 a major west-east freight corridor from the Bay Area across the country to the East Coast.

Other major north-south routes include US-101 and SR 1 toward the coast, SR 70 and SR 99 within the Central Valley, and US-395 along the high Sierra interior. Most other highways are east-west routes or winding mountain roads that traverse Sierra Nevada or Coastal ranges. US-101, SR 99, US-395, the SR 299/44/36 (with US-395) route from Arcata to Reno, and the SR 20/29/53/49 route from US-101 to I-80 are all identified as Strategic Interregional Corridors in the Interregional Transportation Strategic Plan and Tier III Freight Routes in the California Freight Mobility Plan. The state highway network within the region is shown in Figure 4.

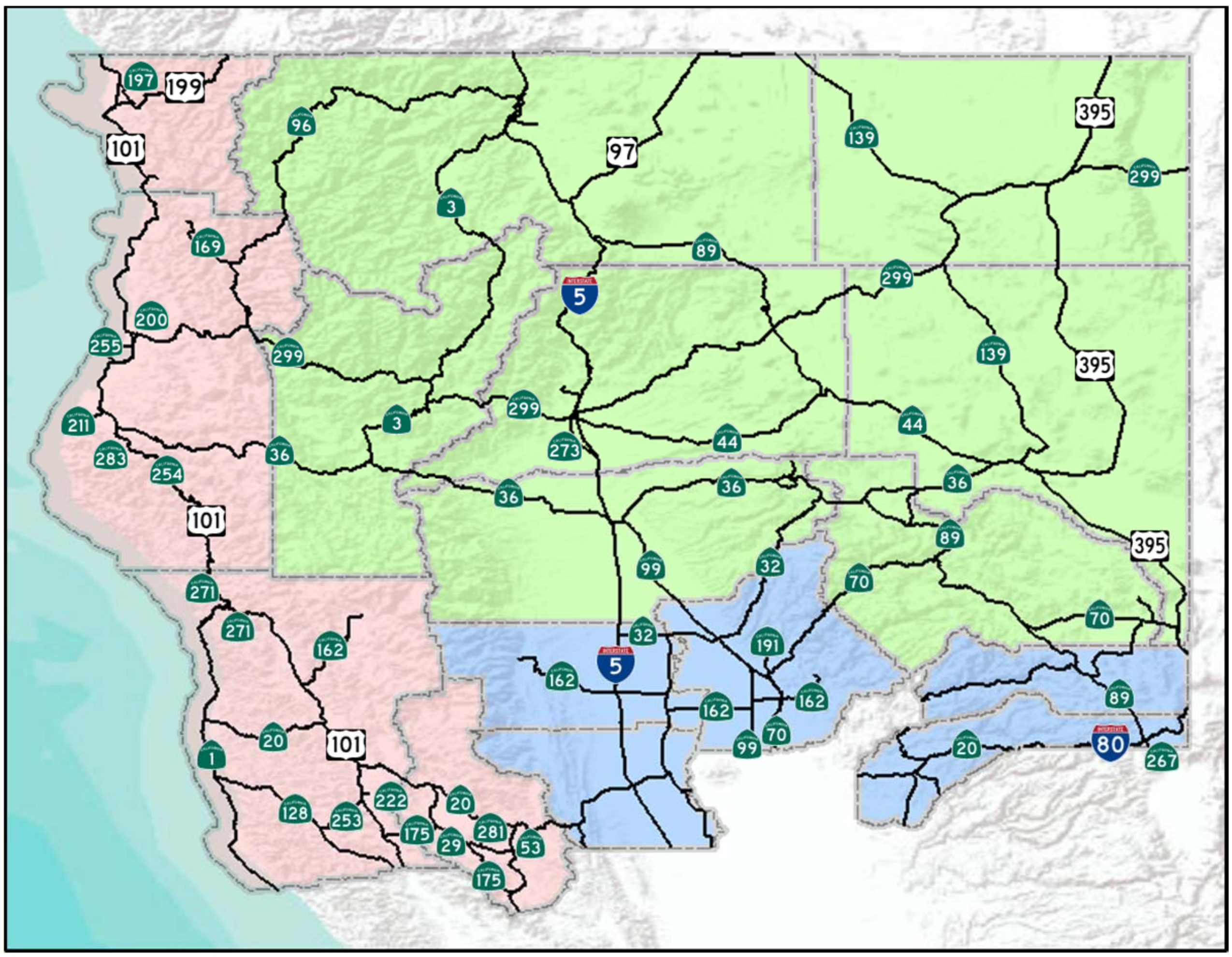


Figure 4 Highway Network

Many of the State Highways in the Super Region do not have convenient detour options due to terrain and other constraints. Using the limited available detours can lead to considerably longer travel times. In many cases where reasonable alternatives are not available, travelers have limited options to either wait or turn around when roadway closures occur.

There are numerous bus transit providers within the Super Region offering a combination of fixed route and paratransit services. With exception of Humboldt County, there is typically one transit provider in each county. Commensurate with the largely rural character of the region, much of the fixed route service is inter-city with limited frequency. However, broader intra-city service is provided in a number of urban centers including Redding, Chico, Eureka, Arcata, and Crescent City. Other transportation services within the Super Region include Greyhound with bus service along US 101, I-5, and SR 99; and Amtrak with Coast Starlight rail with stops in Dunsmuir, Redding, and Chico. The Shasta Regional Transportation Agency has applied for grand funds to establish the North State Express bus service.

2.3 Institutional Setting

Numerous entities are involved in the provision, operation, and maintenance of the region's transportation system. This includes the various public agencies that own, manage, and maintain the region's roadways, and those that operate the public transit systems.

The most prominent of these is Caltrans which manages all state and federal roads. These roads represent the majority of lane miles and are the backbone of the region's transportation system. As previously noted, Caltrans' responsibilities within the Super Region are distributed between three Districts as shown in Figure 1.

- District 1 covers the Super Region's Pacific coast and includes the counties of Del Norte, Humboldt, Mendocino, and Lake. Aside from some coastal plains and inland valleys, the District is largely mountainous thanks to the Coastal Range, and includes towering redwood forests.
- District 2 covers the north east corner of the state, including the counties of Siskiyou, Modoc, Trinity, Shasta, Lassen, Tehama, and Plumas. This region includes the northern end of the Central Valley, the Coastal and Sierra Nevada mountain ranges (including Mt. Lassen, Mt. Shasta, and a portion of the Cascade Range), and the western edge of the Great Basin.
- District 3 covers the Sacramento and Lake Tahoe regions, but the Super Region includes only the counties of Colusa, Glenn, Butte, Sierra, and Nevada. These counties cover parts of the Sierra Nevadas and northern Sacramento Valley.

Each District is responsible for the planning, construction, operation and maintenance of the applicable roads within their District boundaries. The Districts coordinate on an as-needed basis when activities in one District might impact facilities in an adjacent District. Additional coordination and integration in some areas (e.g. online traveler information) is also provided through Caltrans Headquarters.

Other agencies responsible for portions of the roadway network include the various counties and cities, plus the numerous agencies that provide public transit service within the Super Region. Caltrans and these local agencies work together as needed to ensure the appropriate integration of the various transportation networks and services.

These coordination efforts are supported, in part, through the activities of the various Metropolitan Planning Organizations (MPOs) and Regional Transportation Planning Agencies (RTPAs) in the region. In California, MPOs and RTPAs were established to better coordinate transportation planning between various government jurisdictions. The goal is to prevent agencies from operating in isolation or working against each other, which degrades the experience for the user, whom does not care so much about jurisdictional boundaries while traveling. While functionally very similar, MPOs serve more urban, metropolitan settings, while RTPAs serve less urban areas. Each county in the Super Region is part of an RTPA except Shasta and Butte Counties, which are served by MPOs.

Agencies with a less direct role include the Federal Highway Administration (FHWA), US Forest Service, law enforcement agencies, and emergency service providers.

A listing of relevant stakeholder agencies is provided in Appendix A.

2.4 Issues and Challenges

A critical step in the development of the Regional ITS Plan is an understanding of the region's transportation-related issues and challenges. The importance of this step lies in the principle that ITS strategies and projects should be designed specifically to address these challenges. The objective is not to simply implement ITS projects because the technologies are available, but to implement technologies that address the identified issues and challenges within the capabilities of Caltrans and partner agencies. The issues and challenges presented below are not intended to be a listing of all transportation challenges in the Super Region, but rather those most pertinent to possible ITS applications. It should be noted that these issues and challenges are not necessarily presented in order of priority. The level of priority for these challenges often varies by District, county, and by subarea within each individual county. It should also be recognized that many of these challenges are inter-related and overlap.

- Safety – Improving the safety of all travelers is of primary importance to transportation agencies throughout the region. Factors such as adverse weather, winding mountain roads, drivers unfamiliar with the region and isolated areas apply in varying degrees to all of the region's highways and roadways contribute to traveler safety concerns in the region.
- Traveler Information – Making sure that travelers are informed about travel options and current operating conditions can help maximize the efficient use and safety of the transportation system. The type of information that may be useful to the traveler includes roadway conditions, incidents, construction activities, alternative routes, transit schedules, and weather conditions. Two key requirements for traveler information are: the information must be accurate and timely, and the information must be readily available. The large area and rural nature of the region add to the challenge of effectively and efficiently providing the necessary information to travelers.
- Emergency Response and Incident Management – This challenge refers to the ability to identify and react to emergencies or incidents, including managing the non-recurring congestion that may occur due these events. This need is of particular importance in this region because of the isolated nature of some roadway segments and the severe weather that can impact those involved in an incident as well as hamper response efforts. Limited alternate routes also impact emergency responses and management.

- Street and Highway System Maintenance – Improved maintenance of the street and highway system is a challenge that affects all facilities and agencies within the region. For many agencies, maintenance can account for between thirty and forty percent of expenses. The weather in the Super Region has a significant impact on the region's maintenance activities not only as it relates to snowfall, but also the number of days each year that are available for other maintenance and construction efforts. Maintenance activity improvements can reduce disruptions to traffic flows, improve safety for both vehicles and maintenance personnel, and increase the efficiency of these activities.
- Congestion/Roadway Operations – Reflective of its largely rural nature, recurring congestion is not currently a primary issue within the Super Region. Even in the region’s larger urban centers, recurring congestion during the commute periods is limited in scope and duration. However, as the region grows, recurring congestion may become an increasing issue. Even today, minimizing delays on the region’s roadways, especially at traffic signals, is desirable. In addition, non-recurring congestion due to incidents is an issue in the region.
- Transit Efficiency and Effectiveness – Transit efficiency and effectiveness is generally defined as the need to improve service quality and reliability, and improve transit service management. This is a challenge that is consistent throughout the region. For transit system managers, this means making better use of limited resources.
- Freight Movement - Long distances, limited alternate routes and adverse weather can have significant implications with regard to freight movement within and through the Super Region. This can include both impacts to freight movement (e.g. travel delays due to adverse weather or other roadway closures) and to other travelers as a result of freight movement (e.g. truck-related roadway closures, slow-moving vehicles).
- Transportation Planning – Short- and long-range planning is an important function of most of the region's transportation agencies. To be done effectively, this function requires accurate and comprehensive data that can be used to identify problem locations, to quantify magnitude of current problems, to help assess potential benefits, and to evaluate actual impacts. The lack of better planning data is a region-wide issue, affecting all regional and local planning, transit, and public works agencies.

Apart from the issues and challenges presented above where ITS applications may provide solutions, it is important to note the challenge associated with the limited availability of power and communications infrastructure, and balancing this with the operational need and cost of ITS deployment. All ITS field devices require power and most require communication back to a central office or Transportation Management Center (TMC). Due to the rural environment of the region, often the operational need for an ITS Element is at a remote location with limited power and communication options. Currently, Caltrans utilizes varying forms of power and communication strategies, and the use of these strategies varies significantly among the Districts. Finding a cost-effective solution on a site-by-site basis remains a challenge for future deployments.

2.5 Existing ITS Applications

ITS is not a new concept in the Super Region. The region has deployed several ITS applications. An understanding of these existing ITS applications is critical to the development of this ITS Master Plan. These applications can form the building blocks for an integrated regional Intelligent Transportation System. Most of these applications have been implemented by Caltrans, although some local agencies and transit providers have also implemented ITS applications.

An overview of existing ITS initiatives in the Super Region is provided below. A more detailed inventory of ITS elements is provided in Appendix B.

- Traffic Management Centers (TMC) – A TMC is central location for the collection, processing, and dissemination of information used for management activities. A TMC relies on a communication link between the center and the various monitoring and control devices located in the field. Each Caltrans District has a TMC.
- Traffic signal and systems - Traffic signals are the principal form of technology application for arterial traffic management. Various technologies can be deployed to make traffic signals more "intelligent." Those implemented to varying degrees by Caltrans and some of the larger urban jurisdictions include advanced detection, interconnected signals (including across jurisdictions), communication links to the TMC, centralized systems, transit signal priority, and emergency vehicle pre-emption.
- Ramp metering – Ramp metering systems break up platoons of traffic entering a freeway in order to improve operations on the freeway. They are most effective in areas prone to recurrent congestion and are typically deployed in high volume urban areas. While District 3 has plans for ramp metering on SR 99 through Chico, there is currently only one set of ramp meters installed, at the SR 99/Skyway Road interchange. However, these meters are not currently operational. District 2 has a Freeway Ramp Meter Implementation Plan (District Directive DP-09, April 2008). This addresses how, where and when ramp meter actions are to be undertaken. District 2 also has ten locations identified in the state Ramp Meter Development Plan. To date, however, mainline I-5 volumes have not reached the threshold for action in either location.
- Closed circuit television (CCTV) cameras – CCTV systems are used to provide visual images of highway operations. These images can then be used by TMC operators to visually monitor and verify conditions, and to verify operation of other equipment (e.g. CMS messages, signals). They are also accessible to the traveling public through the use of traveler information applications. This technology is already widely used by all three Caltrans Districts. According to inventory data provided by the Districts, there are currently 127 CCTV installations within the Super Region. Factors considered in the deployment of CCTV cameras include: 1. Operational need from the TMC, 2. Maintenance need, and 3. Public input (for traveler information). In general, cameras have been deployed along the most traveled corridors such as I-5 and I-80, and on key mountain passes.
- Traffic detection – Detection devices and systems can take numerous forms and have different uses. These include detectors at intersections used to support the operation of individual signals, devices (permanent or non-permanent) deployed to collect data as part of Caltrans' Census program, and detection devices that have a communication link

to a TMC and provide real-time or near real-time information. The latter provides data that may be used by system managers to provide timely responses to changes in demand and to incidents, and to support traveler information and Caltrans' statewide Performance Monitoring System (PeMS). It is this latter type that is the focus of this plan. In all cases, the data collected (e.g. speed, volume, vehicle classification, etc.) and detection technology used (e.g. loops, microwave, etc.) can vary. There are currently a number of detection stations along I-80 in Nevada County that are connected to the District 3 TMC. While Districts 1 and 2 both currently have numerous detection stations used for signal operation and traffic census purposes, neither currently have stations that provide real-time data.. Historical data from these stations may be retrieved on-site, and used to support planning activities. Caltrans District 3 has also deployed a limited number of Bluetooth readers which record a passing cell phone's MAC address unique to each phone. A series of these readers can then be used to assess travel times and speeds. While Bluetooth reader systems do not capture every passing vehicle, they can use ratios of sampled vehicles to approximate changing demands and route choices. Currently there is only one Bluetooth reader station in the Super Region, on SR 70 outside Oroville.

- Changeable Message Signs (CMSs) – CMSs are large electronic message boards capable of displaying a variety of written or graphic messages to passing motorists. They represent a primary means of providing en-route traveler information with over 70 currently deployed by Caltrans across the region. These signs are typically located at key decision points such as highway junctions. Within the Super Region, most CMSs are located along the I-5, US-101 and I-80 corridors.
- Extinguishable Message Signs (EMSs) – EMSs are typically smaller signs that convey a singular message and are either turned on or off as needed. EMSs can be part of a larger "system" (e.g. automated safety waring system) or stand-alone. The former are described separately below. Within the Super Region, the most common types of stand-alone EMSs are "Chain Up" signs that are used to inform travelers that they should use chains on their tires due to snowy road conditions. Currently there are two installations along I-5 in Siskiyou County.
- Highway Advisory Radio (HAR) – HAR systems provide traveler information to the motorist via the car radio. Typically HAR systems involve the use of dedicated AM radio frequencies/channels and have a broadcast range of ½-2 miles. A HAR system can be used to disseminate a significant amount of traveler information, using a live message or pre-selected taped messages. In addition to the transmitter, HAR deployments also include a sign with flashers (HAR flasher) that can be activated when a message is being broadcast and extinguished when there is no need to communicate a message. Caltrans currently has 35 existing HAR installations across the Super Region. These are generally located in critical areas such as key decision points, urban areas, mountain passes, tunnels, and areas prone to special conditions.
- Road Weather Information System (RWIS) – RWIS involves the use of sensors and instruments to automatically collect weather and roadway surface information. RWIS stations can collect information about temperature, humidity, wind speed, visibility, precipitation type and rate, and roadway icing. The main purpose of the RWIS is to facilitate the scheduling and dispatch of roadway maintenance and snow clearing crews. This data may also be used to initiate traveler information messages. There are 40

RWIS currently deployed by Caltrans in the Super Region. They are located in areas prone to critical weather conditions, such as rainy areas and passes prone to ice. For this reason, all of the existing Upstate RWIS locations are along the coast or in the mountains; they are not needed in the Central Valley.

- Automated safety warning systems – In the context of this Regional ITS Plan, automated safety warning systems refer to localized systems that include a device that detects a particular condition (e.g. speed detector, RWIS) and a sign (e.g. EMS) to inform motorists of that condition. Note that while these safety warning systems encompass some of the devices described above, they are called out separately because they are, in effect, closed systems that operate in isolation from the TMC. Within the Super Region, examples of safety warning systems deployed by Caltrans include those to alert drivers of high speeds approaching a curve or a reduced speed zone, slow vehicles entering the roadway ahead, cyclists on bridges or in tunnels, high winds, and ice on the roadway.
- Caltrans roadway traveler information – Caltrans maintains a centralized 800 number (1-800-GAS-ROAD), a web site (www.dot.ca.gov/hq/roadinfo), and a QuickMap mobile app that can provide travelers with a variety of roadway information. As part of its main and district-specific websites, Caltrans provides access to a variety of current roadway travel information. This includes planned lane closures, CCTV cameras, traffic maps, and highway conditions. This information is also presented graphically through Caltrans' QuickMap webpage and app, as well as the multi-state One-Stop-Shop (OSS) website. These resources also provides access to CHP incident, CMS data, chain control conditions, snow plow, RWIS data, weather forecast information, and Waze alert information.
- Roadway travel information data portal – To help maximize the widespread distribution of travel information, Caltrans has established a Commercial/Media Wholesale Web Portal (CWWP) that allows commercial and media Information Service Providers (ISPs) to access Caltrans-generated traveler information. This portal provides a single repository location for ISPs to obtain statewide traveler information in the form of four different commonly formatted data feeds (JSON, XML, CSV, and TXT) so that third party application developers can integrate Caltrans' traveler information data into their application. The information provided incudes: vehicle speed and volume traffic data, CCTV video images, CMS traffic messages, Lane Closure System (LCS) Data, and RWIS weather and fog information
- Weigh-in-motion systems (WIMs) – WIMs measure vehicle weight without the vehicle needing to slow to a crawl, unlike traditional weigh systems. This is done using a pressure plate installed right in the roadway that can use modern algorithms to compute truck weight from individual axle weights, negating the need to have a physical, staffed truck weigh station. There are currently nine weigh-in-motion stations scattered around the Super Region, including three on I-5, two each on US-101 and SR 29, and one each on US-395 and SR 97. These stations are operated the California Highway Patrol (CHP), not by Caltrans.
- Real-time transit vehicle tracking and information systems – A number of transit providers in the region have equipped their vehicles with Automatic Vehicle Location (AVL) systems that are used to generate real-time vehicle tracking information. This information can be used to manage vehicle and operator location, and to provide real-

time bus tracking information to the public. Four providers (Humboldt Transit Authority systems, Lake Transit Authority, Lassen Rural Bus, and Butte Regional Transit) have taken this step by provided the vehicle location data to various ISPs who then make it available to the public through a combination of websites and mobile apps.

- Advanced transit fare payment – Butte County Association of Governments (BCAG) has equipped the entire B-Line fixed route fleet with electronic card readers that allow California State University, Chico students and faculty, as well as Far Northern Regional Center patrons, to use specialized cards to board the B-Line system. Humboldt Transit Authority allows riders to purchase passes anytime and anywhere on their phone using the Token Transit app.

3 WHERE ARE WE GOING?

It is difficult to outline a roadmap without knowing the destination. By detailing the goals of this plan, it is possible to see where we are going, and strategically plan how to get there. This section describes those end goals and the work that must be undertaken to achieve those goals.

3.1 Framework

In order to provide a hierarchical framework within which we can show the evolution of the plan, we have employed a structure of Vision, Goals, Objectives, Strategies, and Tactics. The hierarchy is illustrated in Figure 5. The remainder of this chapter focuses on the goals and objectives of the Regional ITS Plan. The corresponding strategies and tactics are discussed in Chapter 4.

Figure 5 GOST pyramid

3.2 Overall Vision and Goal

The vision for ITS in Upstate CA is to:

> *Provide technology, systems, and equipment to support the transportation goals of Caltrans, the 16 counties, and the local communities within the Upstate California Super Region in a manner that is collaborative and performance-based, thereby maximizing the safety, efficiency, reliability, and overall performance of the transportation system.*

We have defined one overarching goal for ITS as:

> *Improve safety and efficiency of travel for all modes on the highway network*

3.3 Specific Goals and Objectives

This one overarching goal is further defined by nine specific goals that help define the vision. The nine specific goals listed in Table 1 expand the overarching goal, and are illustrated in Figure 6. Each goal is further described below.

Table 1: Specific ITS goals for Upstate CA

Goal Number	Goal Statement
1	Provide accurate, timely, and reliable traveler information
2	Improve highway incident management
3	Improve emergency management
4	Improve safety on the roadway system
5	Improve highway freight operations
6	Improve roadway maintenance
7	Improve transit operations
8	Enhance transportation planning
9	Reduce variability of delays at intersections

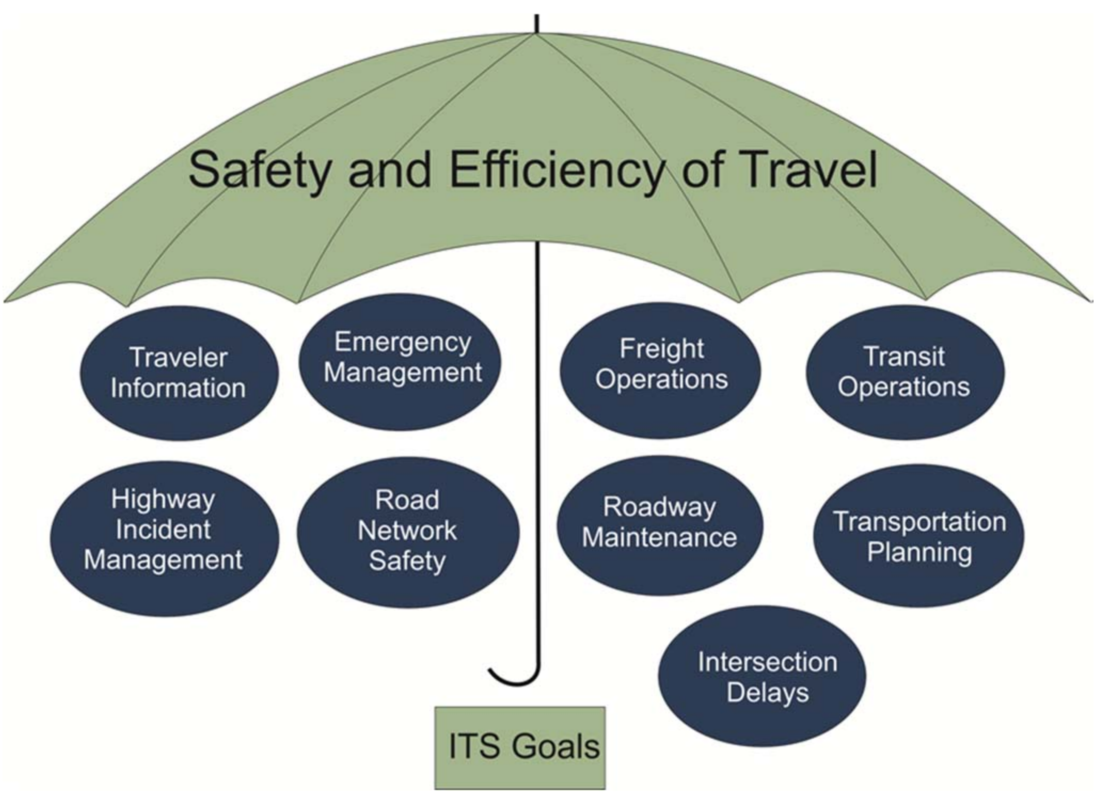


Figure 6 Overarching and specific goals for ITS in Upstate CA

Goal 1: Provide accurate, timely, and reliable traveler information.

Provide timely and predicted road and transit information to travelers planning a trip and to travelers who are already en-route. The intention is to help travelers choose the most appropriate mode and route, and to change their route if conditions change while they are traveling.

Objectives:

- Timely and predicted road and transit information to travelers planning a trip
- Timely road and transit information to travelers en-route

Goal 2: Improve highway incident management.

Provide for better and more efficient management of traffic when there is an incident on the highway. Operators will be made aware of an incident when it is detected and communicated to them (e.g., major collision, heavy snowfall, flooding of roadways), and they will have the ability to direct the incident responders, advise motorists of the most appropriate action to take, and modify traffic signal operation to accommodate changes in traffic patterns as a result of the incident.

Objectives:

- Detect and report incidents in a timely fashion
- Improve operators' situational awareness
- Respond quickly and effectively
- Communication systems for all operators and responders

Goal 3: Improve emergency management.

Allow highway and transit system operators to respond to major emergencies not directly related to transportation, such as fire, flood, earthquake, and tsunamis, which require evacuations and rapid movement of emergency equipment. They will coordinate with emergency services to maximize the efficiency of the transportation network to accommodate these non-recurrent movements.

Objectives:

- Coordinate highway system operators with emergency services
- Increase efficiency of emergency evacuations
- Facilitate movement of emergency services personnel and equipment

Goal 4: Improve safety on the roadway system.

Reduce the numbers of injuries and fatalities on the road and transit systems. It will do this by reducing the number of collisions and improving the safety and security of all modes (auto, truck pedestrian, bicyclist and transit passenger).

Objectives:

- Reduce collisions for all modes on road system
- Improve accommodation of bicycles, pedestrians, transit and commercial vehicles

Goal 5: Improve highway freight operations.

Improve freight operations through support for new technology in trucks, and reduction of delays to trucks through enforcement activities and traffic signal operation at key locations.

Objectives:

- Reduce delays to freight
- Support autonomous and connected trucks
- Support electric trucks

Goal 6: Improve roadway maintenance.

Improve safety for workers and travelers at work zones, keep the highways open longer during adverse winter conditions, and improve the maintenance of roads through improved pavement and bridge condition monitoring.

Objectives:

- Improve winter maintenance activities
- Improve efficiency and safety in work zones
- Improve pavement and bridge conditions assessment
- Achieve high reliability of ITS equipment
- Improve maintenance vehicle fleet management

Goal 7: Improve transit operations.

Use technology to improve the speed, reliability, convenience and safety of transit.

Objectives:

- Improve speed, reliability, and convenience of transit
- Improve on-board and off-board safety and security
- Detect and respond quickly to transit incidents
- Improve coordination of multi-agency transit services

Goal 8: Enhance transportation planning.

Enable better transportation planning for all modes by providing up to date data that efficiently supports transportation planning activities and continuous measurement of performance of the transportation system.

Objectives:

- Provide comprehensive data required by the transportation planning process
- Measure performance of transportation network in terms matching transportation planning objectives
- Update, coordinate, and/or consolidate Regional ITS Architectures regularly
- Support data needs for tracking and reporting progress towards federal and statewide performance measure targets

Goal 9: Reduce variability of delays at intersections.

Allow for more efficient operation of intersections throughout the network, to reduce both the duration and the variability of delays.

Objectives:

- Minimize delay at signalized intersections
- Improve operations at unsignalized intersections
- Provide timely and reliable information to operators

4 WHAT WILL WE DO?

This section describes the ITS-related strategies and tactics that may be used or deployed to achieve the goals and objectives described in the previous chapter. As illustrated in Figure 5, the objectives describe what needs to be done to achieve each goal, while the strategies describe the actions and capabilities that are required in order to reach each objective. Tactics, in turn, represent the various ITS elements or devices that will be deployed and the practices and procedures that will be implemented.

4.1 Overview

ITS encompasses a broad range of strategies and tactics. The key to developing a useful plan that is achievable is to identify those strategies and tactics that match the characteristics, challenges, goals, and objectives of the region.

Many of the more commonly used ITS strategies and tactics tend to be most applicable to urbanized areas or semi-rural corridors that have very high levels of transportation activity. However, the Super Region is largely rural in nature and very little of it falls into either of these categories. As such, the strategies and tactics contained in this Regional ITS Plan are intended to reflect the different characteristics between the rural and urban environments. These differences can include longer trip lengths, a lack of alternative routes, and a higher percentage of travelers unfamiliar with the area. In addition, the larger distances, rugged terrain, and remoteness in rural areas can make maintenance, providing power, and communication more challenging.

Other factors considered in identifying appropriate strategies and tactics for the Super Region included the relatively short plan horizon (ten years), the relatively stable transportation activities expected within the ten-year timeframe (limited expected growth), existing and expected communication system constraints, and the likely penetration level of advanced technologies such as connected vehicle/automated vehicle (CV/AV) applications during the plan period.

Based on analysis of the characteristics of the Super Region and discussions with the stakeholders about their aspirations and capabilities, the strategies and tactics proposed largely represent the enhancement of existing ITS capabilities to fill the gaps, rather than new strategic directions. Furthermore, these strategies and tactics are generally applicable throughout the Super Region, but specifics of their deployment will be customized to suit the conditions within each Caltrans District. Factors that influence differences between the Districts may include the differences in geography, types of weather encountered, travel volumes, facility types, population densities, and operational and maintenance capabilities.

Given funding, utility limitations and other constraints, the focus is to complete the core system currently under development. Continuously evolving technologies introduce a factor of uncertainty. The strategy to build out the planned ITS system using elements already proven effective entails the least risk and highest return on investment. Developing foundational elements that have been proven effective will maintain system viability during deployment of future technologies.

4.2 Mapping Strategies and Tactics

An important element of the ITS planning process is understanding the relationship between the stated goals and objectives of the region and the ITS strategies and tactics being deployed. This relationship is summarized in Table 2 which lists the strategies and tactics that support each of the goals and corresponding objectives described in Chapter 3. Matrices further detailing the mapping from objectives to strategies, and strategies to tactics are provided in Appendix C.

It is useful to note that there is not necessarily a one-to-one relationship between objectives to strategies, and strategies to tactics. Some objectives may be supported by more than one strategy, and some strategies will support more than one objective. In turn, some strategies may be supported by more than one tactic, and some tactics will support more than one strategy. No tactics are listed that do not support at least one of the strategies. This ensures that there are no "widows" or "orphans", and every activity and ITS element clearly supports the stakeholders' identified goals and objectives. This is illustrated by the matrices provided in Appendix C.

Many of the identified strategies and tactics enhance the ability to monitor the operating and physical conditions of the transportation network. This, in turn, allows operators to better manage and maintain the network, and to provide information to travelers.

Table 2: Goal-Objectives-Strategies-Tactics (GOST) Matrix

Objectives	Strategies	Tactics
Goal 1. Provide accurate, timely and reliable traveler Information		
Provide accurate, timely, and reliable road and transit information to travelers planning a trip Provide accurate, timely, and reliable road and transit information to travelers en route	• Monitor/collect data on current conditions • Provide information to road travelers • Provide information to transit travelers • Provide information to 3rd Party information services	• CCTV • RWIS • TMS • Travel time monitoring • Transit vehicle tracking/automated vehicle location (AVL) system • 3rd party resources • Connected vehicle (CV) technology (infrastructure) • CMS • HAR • Website • Phone system • Mobile app • Reverse 911 notification system • Portable CMS • Real-time transit information system • Data warehouse • Data portal
Goal 2. Improve highway incident management		
Detect and report incidents in a timely fashion Improve operators' situational awareness Respond quickly and effectively	• Monitor/collect data on current conditions • Automate identification of incidents • Respond to incidents with appropriate emergency services and maintenance • Ensure good communications (data and voice)	• CCTV • RWIS • TMS • 3rd Party resources • Automated incident detection system • Advanced 1st responder reporting systems (e.g. Responder project) • Incident response procedures and protocols • Communication upgrades

Objectives	Strategies	Tactics
Goal 3. Improve emergency management		
Coordinate highway system operators with emergency services Increase efficiency of emergency evacuations Facilitate movement of emergency services personnel and equipment	• Include highway operations and maintenance staff in emergency planning • Maximize capacity of emergency evacuation routes • Facilitate emergency vehicle response • Ensure good communications (data and voice) • Provide info to travelling public	• Response procedures and protocols • Emergency vehicle preemption • Active traffic management system • Advanced 1st responder reporting systems (e.g. Responder project) • Communications network upgrades • CMS • HAR • Travel info website • Travel info phone system • Mobile app • Reverse 911 • Data portal
Goal 4. Improve safety on roadway system		
Reduce collisions for all modes on roadway system Improve accommodation of bicycles, pedestrians, transit, and commercial vehicles	• Reduce collision risk factors through relevant driver information • Reduce collision risk factors at signals • Accommodate all modes better at signals • Monitor roadway system for adverse conditions, incidents	• Automated safety warning systems • CMS • HAR • CV technology • Automated vehicle (AV) Infrastructure enhancements • Advanced signal operation/equipment • CCTV • RWIS • TMS
Goal 5. Improve highway freight operations		
Reduce delays to freight Support autonomous and connected trucks Support electric trucks	• Speed up commercial vehicle inspections • Improve truck operations at traffic signals • Provide AV/CV infrastructure • Provide EV charging infrastructure	• Commercial vehicle operation (CVO) applications (e.g. WIM) • Advanced signal operation/equipment • CV technology • AV Infrastructure enhancements • EV charging stations at rest areas

Objectives	Strategies	Tactics
Goal 6. Improve roadway maintenance		
Improve winter maintenance activities Improve efficiency and safety in work zones Improve pavement and bridge conditions assessment Achieve high reliability of ITS equipment Improve maintenance vehicle fleet management	• Monitor weather conditions • Improve vehicle guidance in adverse weather • Automate speed limits, traffic controls, and enforcement in work zones • Automate monitoring of pavement conditions • Automate monitoring of bridge parameters • Automate monitoring of all ITS devices' health and performance • Monitor roadway integrity • Monitor maintenance vehicle location • Monitor vehicle condition	• RWIS • CCTV • On-vehicle weather condition sensors • 3rd party data resources (e.g. forecasting services) • CV technology (infrastructure and maintenance vehicle) • AV Infrastructure enhancements • On-vehicle sensors for deploying chemicals • Construction area ITS trailers • Automated pavement condition and marking data collection (on-vehicle instrumentation/detectors) • Bridge monitoring systems • Automated ITS device performance measuring and diagnostics tool (Information Relay) • Slide monitoring/detection • Flood monitoring/detection • Maintenance fleet AVL • Maintenance vehicle diagnostic system
Goal 7. Improve transit operations		
Improve speed, reliability, and convenience of transit Improve on-board and off-board safety and security Detect and respond quickly to transit incidents	• Improve bus operations at traffic signals • Monitor bus status (e.g. location, on-board conditions, vehicle condition) • Provide/improve real time information to transit riders • Provide fare payment options • Coordinate bus arrivals and departures • Collect timely and accurate data on	• Transit signal priority • Transit vehicle tracking/AVL system • Vehicle diagnostic system • Automated passenger counting system • Advanced fare payment • Real-time transit information systems • CCTV (on-vehicle) • Radio on buses

Objectives	Strategies	Tactics
Improve coordination of multi-agency transit services Improve transit fleet management	existing conditions • Reduce collision risks	• Communication upgrades • Inter-operator communication and coordination • Vehicle safety/crash avoidance systems
Goal 8. Enhance transportation planning		
Provide comprehensive data required by the transportation planning process Measure performance of transportation network in terms matching transportation planning objectives Ensure conformance with federal ITS architecture requirements Support data needs for tracking and reporting progress towards federal and statewide performance measure targets	• Collect transportation system performance and operations data (e.g. O-D matrices, point-to-point travel times, traffic volumes, bicycle traffic at traffic signals, speeds, bus passengers) • Archive data • Maintain Regional architecture	• TMS • Travel time monitoring (e.g. Bluetooth Readers) • 3rd party data • System performance measurement and reporting • Advanced signal operation/equipment • Automated passenger counting system • Update, coordinate, and/or consolidate Regional ITS Architectures regularly • Data warehouse
Goal 9. Reduce variability of delays at intersections		
Minimize delays at signalized intersections Improve operations at unsignalized intersections Provide timely and reliable information to operators	• Regularly review and re-optimize signal timing • Have traffic signals respond to real-time traffic conditions • Monitor/record signal heath and performance 24/7 • Measure actual travel times to quantify delays • Monitor traffic performance at key unsignalized intersections • Connect Caltrans signals to TSMSS server per Traffic Signal Operations Business Plan • Provide active driver-assistance at safety-critical intersections	• Advance signal operation/equipment • Travel time monitoring (e.g. Bluetooth Readers) • 3rd party data • TMS • Automated safety warning systems • Asset management system • CCTV • Intersection queue detection • System performance measurement and reporting • Communications upgrades

4.3 Tactic Functional Areas

As shown in Table 2, there is an extensive list of potential ITS tactics applicable to the Super Region. While some tactics primarily support one strategy, many may support multiple strategies. In order to simplify the description and avoid duplication, it is useful to categorize the tactics according to the primary functional area they support. The functional areas are:

- Functional Area A: Highway System Monitoring - Information regarding the condition of the highway system is the foundation for most management and maintenance functions. Knowing network conditions helps system managers and operators determine the appropriate management or operational action to take. Highway system monitoring tactics support traffic management, traveler information, and maintenance decisions.
- Functional Area B: Traffic Operations and Management - This functional area covers activities and equipment that manage the flow and safety of traffic. The tactics selected recognize the largely rural nature of the region, with limited urban areas and little recurring (non-incident related) congestion; few arterial networks with signal systems; and most signals operating as stand-alone, non-coordinated signals.
- Functional Area C: Traveler Information Management - In the absence of active traffic management, the primary way to control or manage traffic is by informing travelers of prevailing conditions. This helps them manage travel choices including route, mode, timing, and speed. This area encompasses a range of tactics that inform travelers both pre-trip and en-route using data and information gathered from monitoring systems, weather reports, radio reports, dispatch and maintenance personnel, and police.
- Functional Area D: Maintenance Management - This functional area covers ITS equipment that can support maintenance of the roadway system. For example, it includes roadside or vehicle-mounted devices that detect pavement or structure conditions. This area also includes tools that may improve the effectiveness of ITS device maintenance (e.g. self-diagnostic ITS equipment, asset management systems).
- Functional Area E: Transit Management - Within the Super Region there is currently limited transit service, with many small services operated by local or county-wide agencies. The stakeholders do not anticipate significant changes to transit services or operations within the ten-year life of the plan. The tactics identified in this functional area are intended to make existing operations more efficient and more attractive to riders.
- Functional Area F: System Integration and Management - This functional area includes tactics which support the effective management of the transportation system. Primary among these is the communication network that connects ITS elements, as well agencies and individuals. Management centers that allow for centralized and coordinated monitoring and operation are another example. This area also includes procedures and protocols for inter-agency coordination.

  This area also includes Connected Vehicle (CV) and Autonomous Vehicle (AV) tactics. This was done because different applications within each can support a variety of the functional areas. In general, CV and AV applications are considered to be longer-term for the Super Region. The implications of CV and AV are discussed further in Chapter 6.

The classification of tactics by functional area is presented in Table 3. Descriptions of each tactic are provided in Appendix D.

Table 3: Tactics by Functional Area

Tactic ID	Tactic
A. Highway System Monitoring	
A1	CCTV Cameras
A2	Roadway Weather Information Systems (RWIS) Stations
A3	3rd Party travel information resources
A4	Traffic Monitoring Stations (TMSs)
A5	Travel time monitoring (e.g. BTR)
A6	Slide monitoring/detection
A7	Flood monitoring/detection
A8	Intersection queue detection
B. Traffic Operations and Management	
B1	Advanced signal operation/equipment
B2	Automated Safety warning systems
B3	Emergency vehicle pre-emption (EVP)
B4	Ramp metering
B5	Automated performance reporting
B6	Commercial Vehicle operations (CVO) Applications
B7	Electric Vehicle (EV) charging stations
B8	Active Traffic Management
B9	Automated incident identification system
C. Traveler Information Management	
C1	Changeable Message signs (CMSs)
C2	Highway Advisory Radio (HAR)
C3	Traveler Info Website Enhancements
C4	Traveler Info Phone System Enhancements
C5	Traveler Info Mobile App Enhancements
C6	Reverse 911 notification system
C7	Real-time multi-modal information system
C8	Data portal
C9	Portable CMS
D. Maintenance Management	
D1	Maintenance fleet tracking/automated vehicle location (AVL) system

Tactic ID	Tactic
D2	On-vehicle weather condition sensors
D3	Automated pavement and marking data collection
D4	Bridge monitoring systems - bridge condition instrumentation/detectors
D5	Automated asset management tool
D6	Construction area ATMS/ITS trailers
D7	Automated roadway treatment
D8	Vehicle guidance systems
D9	Vehicle diagnostic systems
E. Transit Management	
E1	Transit vehicle tracking/ AVL system
E2	Advanced Fare Payment
E3	Vehicle diagnostic systems
E4	Real-time transit information systems
E5	Transit signal priority (TSP)
E6	Automated passenger counting system
E7	On-vehicle CCTV
E8	Inter-operator communication and coordination
E9	Transit vehicle safety/crash avoidance systems
F. System Integration and Management	
F1	Satellite Traffic Management Center (TMC)
F2	Communication upgrades
F3	Regional architecture
F4	Experience sharing
F5	Incident response procedures and protocols
F6	Emergency response procedures and protocols
F7	District coordination
F8	Archive data management/Data warehouse
F9	System performance measurement and reporting
F10	District center-to-center (C2C) integration
F11	Connected vehicle (CV) technology
F12	Automated Vehicle (AV) infrastructure enhancements

4.4 The 10-Year ITS Plan

During the development of the Regional ITS Plan, input was solicited from stakeholders to identify those tactics and ITS applications that best address the region's primary challenges and goals. The resulting set of tactics, referred to as ***"Tier 1" tactics, represent the priorities for ITS deployment by public agencies within the Super Region over the 10-year timeframe of this plan***.

This section provides a brief description of each of the recommended Tier 1 tactics. In many cases, this description also identifies the types of locations or conditions for which each tactic will be appropriate. Details regarding the proposed deployment (e.g. locations) of the Tier 1 tactics are provided in Appendix E.

Estimates of initial capital cost and ongoing annual operations and maintenance costs are also provided. These are derived from national ITS cost databases and input from Caltrans District staff. It is important to recognize that many of these tactics involve the installation of ITS devices in remote areas, and that they will require power connections and communication links to a TMC. The costs for these connections can vary significantly depending on several variables such as proximity to existing networks (e.g. are there nearby power sources or fiber network) and technology used (e.g. solar versus grid, wireline versus wireless). As such, the estimates presented in the descriptions below cover only the typical installation of the corresponding device, exclusive of these connections.

As previously noted, these tactics are generally applicable within each of the counties and Districts in the Super Region. However, specifics of their deployment will be customized to suit the conditions within each county and District.

This plan does not establish priorities or schedules for the specific ITS elements and locations that are proposed. It is assumed that the ITS elements presented in this plan will most likely not be implemented as stand-alone projects, but rather integrated into larger transportation improvement projects. As these improvement projects are elevated to near-term programs, the ITS elements listed here will be included in the project design, in a manner consistent with the applicable ITS architecture (see Section 5.3 for further discussion).

While "Tier 1" tactics represent those of a higher priority and are expected to be actively pursued for implementation within the timeframe of this plan, there are many others that apply to the Super Region. These "Tier 2" tactics that:

- May simply have a limited need at this time, but may be considered for the longer-term
- May be of interest to agencies in the region but there are currently no specific proposals for implementation within the timeframe, or
- May be of interest within the timeframe, but are likely to be the responsibility of entities outside the region (such as Caltrans HQ as part of broader state-wide programs, or the private sector).

A brief description of the all tactics is included in Appendix D. As this plan is reviewed and updated in coming years, the continuing rapid changes in technology are likely to change these priorities, and some tactics may become more suitable for "Tier 1".

4.4.1 Functional Area A: Highway System Monitoring

This functional area covers a variety of tactics used to monitor the physical and operating conditions of the highway system. In turn, highway system monitoring tactics support a variety of traffic management, traveler information, maintenance, and transit management activities.

A1: CCTV Cameras	
Cameras allow TMC operators to visually monitor and verify conditions, and to verify operation of other equipment (e.g. CMS messages, signals). Images from CCTV cameras can also assist travelers by combining with traveler information systems to warn drivers of hazardous environmental conditions. This multi-functionality provides high cost-effectiveness compared to other, more focused monitoring devices such as detector stations. This tactic encompasses new CCTV camera installations, as well as enhancements to existing installations (e.g. camera upgrades, lighting for better night-time visibility). This technology is already widely used in all three Districts, however expanded coverage is desired. Locations at which new CCTV camera deployments will be most beneficial include mountain passes, highway junctions and signalized intersections. The majority of these locations will be within Caltrans jurisdiction.	
Capital Cost: $75,000-150,000 Assumes cabinet and mounting pole. For more remote locations, power and communication costs can vary significantly. Additional costs may include maintenance pullout and guardrail.	Annual O&M Cost: $2,000

A2: Roadway Weather Information Systems (RWIS) Stations	
RWIS stations allow TMC operators and maintenance personnel to know what weather conditions the roadway is experiencing. These stations support maintenance operations by providing information on roadway and environmental conditions that could affect maintenance deployment and scheduling. They also support traveler functions by combining with traveler information systems to warn drivers of dangerous environmental conditions. While numerous RWIS stations have been deployed throughout the region, additional stations are desired especially along mountain passes and remote segments prone to extreme weather conditions. This tactic also includes expanding or enhancing capabilities at existing locations to improve the sensitivity of monitoring devices, faster refresh rates, and/or new types of detection.	
Capital Cost; $100,000-150,000 Costs vary depending on number and type of sensors, power, communications, etc. Additional costs may include: maintenance pullout and guardrail.	Annual O&M Cost: $5,000 additional cost if communication services are leased

A3: 3rd Party Travel Info Resources	
This tactic involves the use of 3rd party or private travel information services as a supplement or alternative to agency-based monitoring and data collection. It may include simply checking website or mobile app to check current conditions, or may involve agreements for access to data for both traffic management and planning activities. For traffic management, data may include travel times and speeds, which help to identify congestion and incidents. For planning, similar data can possibly be coupled with OD patterns to help to identify recurring congestion patterns, where improvements are warranted. Examples of 3rd party/private sector providers of travel information include Google, INRIX, Airsage and WAZE. This tactic also includes the use of weather forecasting services. This tactic recognizes that it can be more cost effective to purchase data rather than building a system to collect data. Involves developing strategic partnerships between public agencies and private vendors to obtain data in the most cost effective way.	
Capital Cost: Varies. Typically involves only an annual subscription fee; may include staff time for training	Annual O&M Cost: Varies depending on level of data access

4.4.2 Functional Area B: Traffic Operations and Management

Traffic Operation and Management tactics target ways to improve the safety and efficiency of traffic flow on the region's roadways. Tier 1 tactics in this functional area include:

B1 : Advanced Signal Operation and Infrastructure	
This tactic encompasses a variety of elements aimed at improving the safety and efficiency of signalized intersections. It can include the various strategies identified in Caltrans Traffic Signal Operations Business Plan. These include advanced operating strategies (e.g. full actuation, adaptive), pedestrian and bicycle accommodations (e.g., detection, signals, and operating firmware), equipment upgrades (e.g. modern cabinets to accommodate additional ITS equipment), and connecting signals to TMC and the TSMSS server. The applicability of this tactic will vary depending upon the characteristics and needs at individual intersections.	
Capital Cost: Varies depending upon project specifics $40,000-60,000 per intersection for bike detection depending on technology $2,000-$5,000 for controller upgrades $15,000-$20,000 for communication upgrades with cabinet replacement (communication link costs are separate – see Tactic F2)	Annual O&M Cost: Varies

B2: Automated Safety Warning Systems	
This tactic refers to stand-alone (not connected to TMC) systems that monitor a specific condition (e.g., vehicle speed, presence of ice on road, presence of pedestrians or cyclists, approaching vehicle) and provide an alert to approaching vehicles (e.g., EMS, flashing beacon). Future upgrades may include equipment for short range I2V communications to accommodate CV/AV and support displaying warning messages inside the vehicles. The system is autonomous and not connected to a communication system. While some examples exist (e.g., curve warning), this tactic will be expanded to include other locations where an existing high crash risk could be reduced.	
Capital Cost: $100,000-$600,00 Varies greatly depending on type and number of monitoring devices and signs. Costs for power and connection can also vary significantly.	Annual O&M Cost: $1,000 - $5,000 depending on type

B3: Emergency Vehicle Pre-emption (EVP)	
Emergency vehicle preemption at traffic signals can improve emergency vehicle response time and safety. While it is most typically applied in urban areas where the volume of conflicting traffic is high, it may also be applied to isolated signals in remote areas to avoid unnecessary delays.	
Capital Cost: $2,000 - $10,000 per intersection Varies depending on controller upgrade. $400-$1,700/vehicle for emitter	Annual O&M Cost: $200-$1,000

4.4.3 Functional Area C: Traveler Information Management

Traveler information encompasses a range of tactics for disseminating information to travelers. Tier 1 tactics for traveler information include:

C1: Changeable Message Signs (CMSs)	
CMSs (also referred to as variable message signs or VMS) are large electronic signs that can post a range of standard and customized messages. They can be used to provide messages about roadway status (e.g., open, closed, construction, weather, incident, alternate routes) and, in certain circumstances, provide advice to drivers. CMSs are controlled by from a TMC. There are many CMSs deployed on the major routes through the Super Region, often in the vicinity of highway junctions. However, expanded coverage is desired, typically at important decision points such as where alternate routes meet or at locations where it may be advisable for motorists to stop rather than proceed toward a major incident or road blockage.	
Capital Cost: $40,000 to $100,000 - per sign $100,000 to $200,000 – mounting structure Power and communication costs can vary significantly, and are dependent on location. Additional costs may include maintenance pullout and guardrail.	Annual O&M Cost: $5,000 additional cost if communication is leased

C2: Highway Advisory Radio (HAR)	
HAR is limited range radio that includes beacon and radio transmitter and typically a sign to inform approaching drivers that a message is being broadcast. Can allow for a more detailed or extended message than possible with a sign; good for scheduled activities (e.g., construction, major events) where it can forewarn travelers about upcoming conditions and schedule). Although many have been deployed in the Super Region, usually at junctions, expanded coverage is desired – to additional junctions of alternate routes that do not currently have HAR, or at locations where it may be advisable for motorists to stop rather than proceed toward a major incident or road blockage.	
Capital Cost: $125,000 – transmitter/tower $50,000 - HAR flasher Power and communication costs can vary significantly, and are dependent on location. Additional costs may include maintenance pullout and guardrail.	Annual O&M Cost: $600 - $1,000

4.4.4 Functional Area D: Maintenance Management

This functional area covers the ways in which ITS equipment and activities can support maintenance of the roadway/transportation network. Tier 1 tactics in this area include:

D1: Maintenance Fleet Tracking/Automated Vehicle Location (AVL) System	
This tactic tracks the location of maintenance and construction vehicles and other equipment to ascertain the progress of their activities. Checks can include ensuring the correct roads are being plowed and work activity is being performed at the correct locations. Location information can also be used by dispatchers to allocate maintenance vehicles efficiently in response to incidents and emergencies.	
Capital Cost: $5,000 to $15,000 per vehicle Assumes some retrofitting necessary.	Annual O&M Cost: $1,000 per vehicle

4.4.5 Functional Area E: Transit Management

The Transit Management functional area includes tactics intended to make existing operations more efficient and more attractive to riders. Tier 1 tactics for this area include:

E1: Transit Fleet Automated Vehicle Location (AVL) System	
This tactic involves monitoring current transit vehicle location using an Automated Vehicle Location (AVL) System. Vehicle tracking systems support safety and security, help dispatchers allocate resources and support transit information systems. Several transit providers in the Super Region have already equipped their fleet with AVL systems. The tactic includes expanding this to all fleets.	
Capital Cost: $5,000 to $15,000 per vehicle Assumes some retrofitting necessary.	Annual O&M Cost: $1,000 per vehicle

E2: Advanced Fare Payment System	
This tactic manages transit fare collection on-board transit vehicles and at transit stops using electronic means. It allows transit users to use a traveler card or other electronic payment device such as a smart phone. It may also involve integrated electronic payment capability for multiple transit services and other transportation-related fees (e.g. tolls, road use, and parking). Generally, transit agencies are trending toward non-cash transactions using smart cards or mobile devices. This can facilitate transfers on multi-route and multi-system trips. Humboldt Transit Authority currently uses a 3rd party app and the Butte County Association of Governments have e-card readers. A focus of this tactic is to extend non-cash transaction capabilities to other transit providers. As part of this, use of a common system or integration of systems should be explored to make fare payment seamless for the user across the different transit services.	
Capital Cost: Varies depending on type of system 3rd party payment app – N/A	O&M Cost:

4.4.6 Functional Area F: System Integration and Management

This functional area includes ITS elements or devices, plus practices and procedures, which support the effective management of the transportation system. Relevant Tier 1 tactics include:

F1: Satellite TMC	
Construction of a satellite TMC that may be used to distribute everyday management operations, or in the case of emergency. Given the size of the region, the efficiency of operations and maintenance could be improved by constructing satellite TMCs that provide staff in certain subareas to better monitor traffic and equipment, and coordinate their activities. Consideration may be given to setting this up to operate as an alternative TMC in the event of communications link failure to the main TMC. A satellite TMC in Marysville is of specific interest in District 3.	
Capital Cost: $1 million+ Highly variable depending on the scope, magnitude, and existing infrastructure.	O&M Cost: Variable depending on scale, hours of operation, etc.

F2: Communication Upgrades	
Upgrades to provide more robust and reliable communications between field devices and applicable control centers. This may include expanding coverage or enhancing coverage (e.g. reliability, bandwidth) of current systems. Currently employ a variety of technologies and services. This tactic can also include equipment for vehicle-to-infrastructure communication. Applicable throughout the region, especially in remote areas where cellular coverage is limited. Caltrans has expressed a desire to reduce the reliance on leased communications. One element of this tactic is to connect Caltrans signals to the TSMSS server per Traffic Signal Operations Business Plan. For existing signals, this may require new or upgraded communication infrastructure. This infrastructure should be included as part of all new signal projects.	
Capital Cost: Variable by project $200,000/mile for fiber optic cable installation $5,000 per location for DSL or 4GLTE modem	Annual O&M Cost: Highly Variable

F3: Regional Architecture	
The regional architecture and ITS standards provide a framework for technical interoperability. Close coordination and cooperation between various agencies will be required to ensure procedural and institutional interoperability. This may be achieved, in part, through the on-going activity of an ITS Coordinating Committee for the region, and the development of inter-agency agreements.	
Capital Cost: Staff time for training and to prepare	Annual O&M Cost: Ongoing staff time for training and updating

F4: Incident response procedures and protocols	
Development of procedures and protocols to be implemented during various incidents. Development of these procedures in advance allows for more efficient response. Can involve individual agencies or multiple stakeholders, including emergency response providers.	
Capital Cost: Staff time to prepare protocol and provide training	Annual O&M Cost: Ongoing staff time for training and updating

F5: Emergency response procedures and protocols	
Development of procedures and protocols to be implemented in the case major emergencies. Development of these procedures in advance allows for more efficient response. Can involve individual agencies or multiple stakeholders, including emergency response providers.	
Capital Cost: Staff time to prepare protocol and provide training	O&M Cost: Ongoing staff time for training and updating

5 HOW WILL WE GET THERE?

This chapter describes policies and procedures that should be followed in order to effectively implement the deployment plan described in Chapter 4, to achieve the plan's goals.

5.1 Deployment Considerations

The implementation of the projects identified in this Regional ITS Plan will be carried out by a broad spectrum of agencies and private interest groups within a very complex environment. To facilitate the efficient and effective implementation of ITS in the region, several factors must be considered during both the design and deployment of these projects. These factors may be summarized as follows:

- **Interoperability**. To take full advantage of their potential, most individual ITS applications will need to accommodate linkages to other systems and coordination between different agencies. This ability for the different ITS projects and systems to communicate and work with one another is referred to as "interoperability". The regional architecture and ITS standards provide a framework for technical interoperability. Close coordination and cooperation between various agencies will be required to ensure procedural and institutional interoperability. This may be achieved, in part, through the on-going activities of existing standing committees or working groups (e.g., MPOs/RTPAs and technical advisory committees) that meet regularly, by specifically including coordination of ITS planning, operations and maintenance in their standing agendas. More robust coordination could be conducted through an ITS Coordinating Committee for the region, and the development of inter-agency agreements. Further discussion is warranted among the stakeholders to determine the most suitable administrative arrangements.
- **Project Conformance**. Federal funding of ITS Projects will be contingent on projects being in conformance with the Regional ITS Architecture and, by extension, the National ITS Architecture. Federal rules (23 CFR 940) require each ITS project (or the ITS components of larger projects) be subject to a systems engineering analysis, commensurate with the size and complexity of the project. Not only will this provide a vehicle to demonstrate conformance with the National ITS Architecture, but it has been demonstrated to significantly reduce the risks associated with ITS projects. For further guidance, refer to section 5.3, Conformance and Architecture.
- **Standards**. Another element of the federal requirements is that applicable ITS standards be used for all federally-funded ITS projects. The goal of this regulation is to ensure that ITS applications achieve the interoperability necessary to function consistently and effectively nationwide. Use of these standards can help support the design and specification process, and ensure compatibility of interfaces between systems.
- **Intra- and Inter-Agency Cooperation**. While most of the ITS deployments in this Plan will be managed by one Caltrans District, some call for cooperative deployment and operations efforts between multiple jurisdictions. These will require a greater degree of coordination between agencies than might normally be the case. Consideration of the need for formal inter-agency agreements should be included in the planning stages of each multi-jurisdiction deployment, to ensure stability of design, operations and

maintenance of those deployments. Further discussion regarding possible roles and responsibilities is provided in Appendix F.

- **Funding**. During the life of this plan, it is less likely that stand-alone ITS projects will be funded than in previous years. Rather, the majority of the expected ITS deployments will likely be implemented as a component of larger road improvement projects. It is therefore essential that an adequate allowance for ITS elements be included at the programming stage of every infrastructure project, and this be carried through the design and construction phases. Most ITS elements within this Plan should be eligible for funding under programs such as:

    - Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program
    - National Highway Traffic Safety Administration (NHTSA) grants
    - Strategic Highway Research Program (SHRP2)
    - Transportation Investment Generating Economic Recovery (TIGER)
    - Congestion Mitigation and Air Quality Improvement (CMAQ)
    - State Highway Operation and Protection Program (SHOPP)
    - Senate Bill (SB) 1: Road Repair and Accountability Act funding

    The recent passage of SB1 has dramatically changed the financial plan for transportation in California. Through SB1, California is providing a significant new consistent funding source for transportation, investing $54 billion over the next decade for infrastructure, maintenance, and public transit. The additional funding has provided Caltrans and its local partners with critically-needed resources and increased funding for transportation system improvements, as well as repair and rehabilitation.

    District and MPO/RTPA staff should maintain close coordination with Caltrans HQ grants staff to determine potential availability of grant moneys in a timely manner, so that applications for funding may be submitted in a timely fashion. Within many grants programs, multi-agency applications are encouraged, so close coordination among Caltrans Districts, MPOs and other local agencies is highly desirable.

- **Procurement**. The traditional procurement and contract procedures used by agencies vary and may not always be well suited to the unique characteristics of ITS projects. ITS projects may require extensive interagency cooperation, involve public/private partnership agreements, and present privacy issues that need to be addressed. ITS projects also involve the acquisition and placement of high-tech equipment that may require special procurement considerations. It is recommended that both Caltrans and local agencies review their procurement practices to facilitate the most effective and efficient implementations of the deployment plan.

- **Operations and Maintenance**. Successful ITS applications depend to a great extent on the approach taken to provide day-to-day operation of the systems. Project sponsors must have a plan for and devote resources to operations and maintenance. They cannot take a "set it and forget it" approach. They must think through not only how they will get a system running, but how they will keep it running, and how they will maximize its potential benefit. Furthermore, ITS equipment maintenance often requires specialized skills not found within traditional agency signal or electrical maintenance departments. Key issues include the availability of staff, the need for special training, the development of operating procedures, and the budgeting of annual funding.

The importance of properly planning for system maintenance is recognized in the recently published California Transportation Asset Management Plan[5] (TAMP). The California TAMP describes the vision for how good asset management will help to deliver broad transportation goals and fundamental objectives supported by information on current asset conditions, the desired conditions in the future, and the likely conditions given future funding scenarios. The additional funding available through SB 1 provides Caltrans and its local partners with critically-needed resources and increased funding for system repair and rehabilitation to help support an asset management approach.

- **Private Sector Involvement**. ITS is not just a public agency program. In fact, there is often a need to pursue private sector participation in certain areas of ITS. In addition to the manufacture and sale of in-vehicle devices and other products, one of the principal areas of opportunity for private sector involvement is in traveler information. Information generated by public sector systems can be readily obtained and re-packaged for particular audiences. Private motorist aid patrols (that benefit from exposure and advertising) have been used in some areas to supplement the motorist services provided by departments of transportation.
- **Staff Skills and Training**. There are two specific issues related to ITS in this area. Because of the rate of change of technology, it is necessary to continually train technical support staff to be able to efficiently operate and maintain ITS technology. There is a strong argument to support pro-active training so there is a pool of qualified staff available as new technology is deployed, in sufficient numbers to provide backup and avoid critical staff shortages. Within Caltrans and other agencies, there is a need to review and revise technical staff classifications in recognition of the specialized nature of ITS equipment that is not adequately accommodated by staff with traditional electrical and electronic qualifications applicable to traffic signals and other more traditional equipment. As more specialist skills are required for new equipment, smaller agencies are discouraged from adoption because of limited staff capabilities and skills. Consideration should be given to more cooperative agreements for operations and maintenance so that agencies with necessary technology skills can provide service and support to other neighboring agencies that need to participate in ITS projects.

5.2 ITS Implementation Policies

The policies described in this section are intended to help guide the decisions on how ITS should be planned, programmed and implemented, and the roles of the various stakeholders. This is separate from specific guidance to staff on practices and procedures,

Policies that should govern ITS implementation within the Super Region include:

1. Incorporate ITS elements into all highway and roadway improvement projects. Throughout planning and design process, should identify and incorporate all ITS elements that can be usefully deployed in conjunction with the improvements, and

[5] California Transportation Asset Management Plan, January 2018, http://www.dot.ca.gov/assetmgmt/tam_plan.html

include provisions that will cost-effectively facilitate future installation of components that should be deferred until they can be made operational. (e.g., install conduits, cables and stand-alone equipment, but defer items that cannot be effectively commissioned until other systems are in place). Ensure that every highway and roadway improvement project includes adequate funding allowance for the applicable ITS elements.

2. For more complex ITS elements, it may be necessary to define a specific project and seek separate funding. This may include baseline or backbone projects that are necessary to support multiple field deployments (e.g., long distance communications, and CV/AV support systems).
3. Meet all ITS Architecture conformance requirements. Ensure all proposed projects and ITS deployments are in conformance with applicable ITS Architecture requirements. This conformance should be documented, by following the instructions in Caltrans Local Assistance Program Guidelines[6], Chapter 13 Intelligent Transportation Systems (ITS) Program. By documenting that all projects support the agreed functional requirements, compliance is more easily achieved. Note that this is a two-way process: in some circumstances it will be appropriate to modify the Regional ITS Architecture to accommodate new stakeholder needs and new technologies, to demonstrate compliance. (This is further discussed in section 5.3, Conformance and Architecture.)
4. Caltrans provides ITS leadership across the Super Region. Given the preponderance of proposed deployments falling within Caltrans jurisdiction, it will be essential for Caltrans to provide leadership in the development of programs, implementation, operation and maintenance. However, significant coordination with other stakeholders should continue on a routine basis to ensure effective cooperation and support by all relevant agencies. Significant support by regional and local agencies will greatly assist the success of the deployment plan, but leadership by Caltrans is essential to ensure coordination of activities, and to illustrate to other planning, operating, approving and funding agencies that there will be adequate technical and institutional support. This includes policies and principles to guide ownership, operation and maintenance arrangements, as described in Appendix F: Roles and Responsibilities.
5. Review and update the Regional ITS Plan on a regular basis and when applicable trigger events occur. This plan needs to be a living document that can respond to funding opportunities as they arise, changes in technology, changes in priorities that may result from unexpected external influences (e.g., new land use developments, changes in State and Federal government policies, natural disasters), and incremental changes in needs/priorities as improvements are completed. It would be appropriate to schedule an annual review of the plan so that any deployments completed during the previous year can be incorporated into the baseline and new needs and proposed projects can be incorporated into the proposed deployments. In addition, significant events that would change the underlying assumptions should also trigger a review of the plan. (This is further discussed in section 5.5 Maintaining the Plan.)

[6] http://www.dot.ca.gov/hq/LocalPrograms/lam/lapg.htm

5.3 Conformance and Architecture

As previously noted, federal funding of ITS Projects is contingent on projects being in conformance with the Regional ITS Architecture and, by extension, the National ITS Architecture. Federal rules require each ITS project (or the ITS components of multi-disciplinary projects) be subject to a systems engineering analysis. The intent of these rules is to improve the success rate of ITS projects by reducing schedule and cost risks, ensuring that user needs and requirements are met, and ensuring that the appropriate linkages to other systems and coordination between different agencies are accommodated.

To help agencies meet these conformance requirements, FHWA has developed various guidance materials and an architecture database tool (prior version called Turbo Architecture was recently replaced by ARC-IT). While use of this tool can be invaluable, especially for complex, multi-agency projects, it is not required. The regulations indicate that level of effort involved should be commensurate with the size and complexity of the project.

In addition, Caltrans Division of Local Assistance (DLA) has developed project development procedures to assure compliance with the federal ITS regulations. These procedures are described in Caltrans Local Assistance Program Guidelines (LAPG), Chapter 13 Intelligent Transportation Systems (ITS) Program[7]. These guidelines divide ITS projects into three types: Exempt, Low-Risk, and High-Risk projects. The planning and development process to be followed is different for these three types, with the process becoming more involved for higher risk projects.

A repository of statewide ITS architecture resources is also available. The Caltrans-sponsored *Statewide ITS Architecture Assessment and Support* project in 2018 assessed how statewide and regional ITS architectures (RITSAs) have been used in support of both regional transportation planning activities and transportation investments. The project identified a number of institutional barriers preventing RITSAs from being used more effectively, defined a Business Case for RITSAs in California, and provided planning guidance for ITS activities. These resources can be useful to support ITS planning activities in the Super Region, and are provided as part of Caltrans' Statewide ITS Architecture web resource[8].

In addition to the above, it is important to consider the characteristics that define ITS deployments in the Super Region. These include:

- the preponderance of proposed deployments fall within Caltrans' jurisdiction, and are expected to involve little or no integration with other agencies,
- current systems are largely District-specific, with the only integration occurring through the statewide traveler information system (web, phone and mobile app) and the Commercial Wholesale Web Portal (CWWP),

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[7] http://dot.ca.gov/hq/LocalPrograms/ITS/ITS.htm
http://dot.ca.gov/hq/LocalPrograms/lam/prog_g/ch13-2-2012.pdf
Systems Engineering Review Form (SERF) at (http://dot.ca.gov/hq/LocalPrograms/ITS/p07I.pdf)

[8] http://www.dot.ca.gov/trafficops/switsa/

- the strategies and tactics proposed in this plan largely represent the enhancement or expansion of existing ITS capabilities, and do not require new software or cutting-edge technology.

Based on all of the above factors, the proposed conformance and architecture component of this plan consists of the following elements:

- as part of its' ITS leadership role, Caltrans should serve as the "custodian" for the region's ITS inventory/architecture, including those elements deployed by other agencies.
- the ITS inventory/architecture should be divided by District.
- the procedures and forms presented in the LAPG, Chapter 13 Intelligent Transportation Systems (ITS) Program, should be applied for all ITS projects to ensure that the appropriate system engineering and architecture requirements are met.
- the Districts should support statewide ITS architecture efforts.
- the Districts should monitor the *Statewide ITS Architecture Assessment and Support* project for recommendations and requirements related to regional ITS architectures.
- the Districts should follow and apply guidelines provided by HQ related to advanced ITS applications.
- anticipating the future application of ARC-IT software as more advanced and complex ITS elements are deployed, ARC-IT training from FHWA should be requested.

To assist in defining the ITS architecture for the Super Region, and to support the potential future application of ARC-IT, this plan includes the following:

- Listing of stakeholders (Appendix A)
- Inventory of existing (Appendix B) and planned (Appendix E) ITS tactics/devices
- Listing of corresponding ITS service packages (Appendix G)
- Listing of ITS architecture elements (Appendices H)

5.4 Performance Measurement

In order to keep this plan relevant, it is essential to track the extent to which the plan is being implemented and how successfully it is achieving the goals and objectives. The plan's goals and objectives focus performance measurement on outcomes and help define appropriate performance indicators. To remain effective, a strategic plan must regularly revisit and "truth test" goals, objectives, and outcome measures.

Performance measures will quantify the extent to which each objective is being achieved and, in turn, goals are being satisfied. While the stated goals are less tangible and quantifiable, the objectives have been stated in a way that facilitates measurement. The measures of performance defined below will allow measurement of the extent to which each objective is achieved. However, the actual measurement technique, and definition of what outcome can be concluded as achieving an objective, will depend on what strategies and tactics are chosen in a particular environment, so they are not defined in this document. Each sponsoring and operational agency will need to clearly define the suitable performance measurement, and threshold for success appropriate for each project, the local area and the part of the plan being implemented.

Table 4 provides guidance on performance measures that are likely to be appropriate for quantifying the extent to which the objectives listed under each goal are met.

Table 4: Potential Performance Measures

Goals	Performance Measures
Goal 1: Provide timely and useful traveler information	– Extent and accuracy of display: o Road conditions on internet o Transit information on the internet o Transit information on the internet or mobile apps o Predicted travel times on the internet o Predicted travel times on CMS
Goal 2: Improve highway incident management	– Percentage of reported incidents detected automatically – Incident response times (time from incident detection to dispatch of responders) – Incident removal times (time from incident detection clearance of vehicles, obstructions, etc.) – Incident clearance times (time from incident detection to clearance of associated traffic congestion) – Issues identified in post-incident reviews
Goal 3: Improve emergency management	– Issues identified in post-emergency reviews – Time to complete evacuations (time from decision to evacuate to completion of evacuation) – Response times of emergency services (travel time from dispatch to arrival at destination)
Goal 4: Improve safety on the roadway system	– Number of crashes (by location, time, weather, and other relevant variables) – Crash rates by road user type (stratified by relevant variables) – Volume of cyclists on key road segments (measure of demand in response to changes in perceived safety) – Surveys of cyclists' perceived safety levels
Goal 5: Improve highway freight operations	– Freight delays due to enforcement (delays at scales, inspection stations and ad hoc enforcement) – Truck delays at traffic signals (if truck priority measures are adopted)
Goal 6: Improve roadway maintenance	– Length of time roads closed due to snow and ice, and frequency of closures – Vehicle speed compliance in work zones – Safety record within and approaching work zones – Maintenance orders raised as a result of use of ITS
Goal 7: Improve transit operations	– Transit travel time reliability metrics – Transit schedule adherence metrics – Number of transit systems who have implemented ITS elements such as electronic fare payment, real-time transit information, and trip planners – Number of incidents on-board, at bus stops and terminals – Transit rider satisfaction level
Goal 8: Enhance transportation planning	– Roadway miles with traffic detection coverage – Roadway miles or intersections with automated transportation performance measure reporting
Goal 9: Reduce variability of delays at intersections	– Percent arrival on green at signalized intersections – Red occupancy ratio (ROR)/Green occupancy ratio (GOR) to measure effectiveness of green time – Point to point travel times on routes with multiple signalized intersections – Measured delays at key unsignalized intersections

5.5 Maintaining the Plan

As changes in direction within the agencies or for the region as a whole are realized, the plan goals, strategies, and tactics may need to be revised. Thus, the Regional ITS Plan needs to be a living document that can respond to funding opportunities, as well as changes in technology, priorities and needs. While the Master Plan cannot be constantly updated to keep pace with these changes, a process should be established to regularly review and update information in the Master Plan.

The proposed update process includes the following:

- Maintain inventory of ITS devices - The baseline inventory of installed equipment should be kept up to date. This could be done on an on-going basis as new equipment is deployed in the field or through an annual update.
- Conduct routine update of Regional ITS Plan – It is recommended that a routine review of the plan be conducted on a cycle similar to updates of the Regional Transportation Plan (i.e. three years). Elements of the plan should be updated to accommodate the following:
  - Updated inventory of installed equipment
  - Modify the goals and objectives, as appropriate, in response to changing needs
  - Modify strategies and tactics to any changes in goals and objectives, remain consistent with current technologies, and extend the planning horizon to maintain the ten-year outlook
  - Incorporate advances in performance measurement
- Conduct update in response to significant events – In between routine updates, significant events that would change the Regional ITS Plan’s underlying assumptions may also trigger a review of the plan. Examples of potential trigger events are:
  - implementation or completion of a significant plan element,
  - adoption of an updated transportation planning document with corresponding changes to overall goals and objectives,
  - change in a statewide policy that was a direct input to one or more of the plan’s goals and objectives (e.g., statewide CVO policy or operation, statewide AV operational policy, EV policies)
  - change in agreed relationships, roles, and responsibilities of other state and local agencies
  - a major change to the statewide communications system, or
  - entry of “disruptive” new activities or services that change travel patterns.

The “custodian” of the plan should continually monitor the transportation environment and identify any event of sufficient significance that would trigger a specific review of the plan. As noted previously, it is appropriate that Caltrans be custodian of the Regional ITS Plan as part of its’ ITS program leadership role.

Moving forward, it is recommended that in the near-term this plan be broken into separate plans for each District. Most of the material provided in this plan (e.g. goals, objectives, strategies) is common to all three Districts. The primary modification would be to separate out the stakeholder and inventory lists that appear as appendices. Creating separate plans will ease the update process and allow for more flexibility in modifying elements of the plan. This approach recognizes that while coordination and communication between Districts does occur, the level of ITS integration between Districts is very limited at this time. However, this should be re-visited in the future as greater integration of systems occurs.

6 LONG TERM POSSIBILITIES

This section of the plan addresses emerging technology applications that may prove viable in the Super Region at some point in the future. These applications include Connected Vehicles, Autonomous Vehicles, Smart Cities / Smart Regions, and future communication technologies and trends, and how these should be considered as part of Plan Maintenance. It is likely these technologies will first be deployed in urban areas due to cost of technology and level of support required. In addition to a description of these applications, this section discusses how these should be considered as part of Plan Maintenance.

6.1 Autonomous and Connected Vehicles

Autonomous vehicle (AV) and connected vehicle (CV) technologies are often conflated, but are separate concepts that are not necessarily co-requisite. **Autonomous vehicles** ultimately are wholly self-driving, where the user only needs to specify a destination and the vehicle does the rest. AV technology does not start and end with this ideal; however, as there are smaller steps in the lead-up to full autonomous operation. One existing element is adaptive cruise control, where the vehicle maintains speed autonomously. A recently deployed technology is “lane keeping,” where the vehicle is able to stay in its lane, but user input is needed to switch lanes or turn off the roadway. From here, AVs will progress to the point where minimal input is required but a driver is still required to be ready to jump in at a moment’s notice. Eventually, this need will diminish as vehicles become fully autonomous, and devices like steering wheels and pedals can be foregone.

On the other hand, **connected vehicles** are those that communicate with roadway infrastructure and other vehicles. One deployed CV technology is integrated navigation that receives real-time traffic and road condition updates, and can adjust course accordingly. As of today, when an incident occurs, drivers report it through mobile applications like Waze, and other algorithms report it through tracking declining vehicle speeds. Essentially, this requires vehicles to communicate about the incident to infrastructure, which then processes the data and sends it out to other drivers. In the future, the goal is to enable vehicles to directly communicate with each other, spreading messages upstream so that within seconds of an incident occurring, upstream drivers can be alerted and prepare to slow down. Another use for CV technology includes communicating with traffic signals and other vehicles to improve intersection operations.

While AV and CV technology can work independently, combining the two far improves both technologies. AVs can operate better by communicating with each other and the infrastructure, and CVs can demand a faster and more accurate response from a computer than by distracting a human.

Connected vehicles are quickly becoming a reality, and predictions about the arrival and rate of market penetration of autonomous vehicles vary widely. It is not possible to make any confident predictions about the uptake of AVs, nor about the technologies that will be required of ITS equipment to support them. Rather, it is perhaps more appropriate to establish regular reviews of the progress of AV developments, to ensure timely action is taken.

While there are some, largely experimental, connected vehicle applications already deployed, these are generally localized in nature, and there is not great level of consensus or standardization of either processes or equipment. While it is most likely that wireless dedicated short-range communications (DSRC) will be the communications medium of choice, this is by no means certain. The Federal Communications Commission (FCC) is still deliberating alternative uses of the part of the spectrum currently reserved for DSRC. Even assuming DSRC is eventually preserved and protected for CV communications with infrastructure, the rate of change in technology has shown in recent years that too-early deployment of DSRC devices will result in obsolescence of that equipment before it can be widely used for its intended purpose.

The prudent course of action at this time is to establish a schedule for regular review of the progress of AV/CV deployment, the technology required for communications, and the associated regulatory environment. While it may be premature to deploy DSRC and other AV/CV-related equipment, all new ITS equipment should include appropriate interfaces (as far as possible) to allow future connection of such equipment.

Another thing to consider is the effect of AV/CV deployment on the need for existing ITS technologies. If at some point in the future vehicles are communicating with each other and with infrastructure directly, providing travel updates in real time directly to drivers, this could negate the need for infrastructure-to-driver technologies, such as CMS and HAR. Additionally, AVs would be aware of dangerous corners and winter weather conditions long before flashing warning signs could relay the message.

When installing roadside ITS devices, future communications for connected vehicle capabilities should be considered. The two main wireless forms of communication used for connected vehicle applications include DSRC and cellular 4G networks (or 5G in the near future). DSRC is a two-way wireless communications capability that transmits data with low latency (milliseconds) and can be used for safety applications. The low latency of DSRC makes it ideal for safety critical communications, such as crash prevention. Other wireless communications such as 4G and 5G have relatively low latency and can be used for communications where a higher latency tolerance is acceptable.

6.2 Smart Cities / Smart Regions

The “Smart Cities” concept applies to local jurisdictions that integrate their various components using data collection to better and more efficiently manage assets. This means that from the municipal headquarters, analysts can quickly pull data from traffic signals, parking meters, schools, water treatment plants, and so on. The advantage to this connectivity is that the municipality can quickly respond to and correct aberrations, as well as gather historical data to make better decisions moving forward. On a regional level, this concept can be applied to a greater area with perhaps greater reliance on commercial connections, rather than a city-owned fiber/interconnect system.

Similar to with AV/CV technology, the prudent course of action towards smart cities/regions technology is to establish a schedule for regular review. While current technologies might be too expensive and specialized for deployment in the Super Region, future trends might enable adoption to be more economical.

6.3 Future of Communications

One of the key issues facing the Super Region is communication, which can often be difficult and expensive to extend to remote locations. While Caltrans has an expressed interest in an expanded agency-owned fiber optic network, the cost for such a network that would effectively cover the Upstate Region is cost prohibitive. In recognition of this, Caltrans has been involved in a number of initiatives to enhance the deployment of broadband communication networks through collaboration with private sector broadband providers, California Governor's Executive Order S-23-06 Twenty-First Century Government directed the establishment of the California Broadband Task Force, of which the California Department of Transportation (Caltrans) is a member, to bring together public and private stakeholders to better facilitate broadband installation, identify opportunities for increased broadband adoption, and enable access to and deployment of new advanced communication technologies. Meanwhile, California Legislation (AB 1549) requires Caltrans to notify companies working on broadband deployment of Caltrans-led highway construction projects and authorizes those companies to coordinate with Caltrans on the installation of conduit with state right-of-way. In some cases, agreements may include the installation of conduit and fibers for Caltrans' use, at no cost to Caltrans.

However, given the size and sparse population of the Upstate region, a comprehensive wired broadband network is not feasible. Fortunately, technology is advancing in a direction that will lower the cost of remote access over time. This is being done through expanded cell coverage and new satellite internet technology.

While much of the Super Region lacks reliable cellular communication, telecom companies are constantly expanding existing service and rolling out faster and more reliable technology. It is probable that in the future, this expansion will ease the burden of remote communications. One issue that remains is that in the event of a major disaster, cell networks can become overloaded, hindering official communications to travelers and infrastructure, and negating any benefit.

An alternative technology in times of crisis is satellite internet. Satellite internet has the perk of providing almost universal coverage without a cost function related to remoteness. This means that a lone ITS element far away from any wired system can communicate for a similar cost to an element much closer to the wired network. However, experience by Caltrans District 1 suggests that reliability can be an issue in areas of rugged terrain, or even due to interference from clouds and trees. In addition, the cost can still be prohibitively expensive for most agencies to consider. There has been interest in establishing a cheaper network of internet satellites, or at least high-altitude internet drones, as SpaceX and Facebook have demonstrated[9]. This could drastically reduce the cost of communication for remote ITS elements. Paired with improving solar and battery technology, and soon it may be possible to install and maintain ITS virtually anywhere.

[9] Stark, Harold, *SpaceX and Facebook Are On A Race To Globalize The Internet*, Forbes, May 11, 2017, https://www.forbes.com/sites/haroldstark/2017/05/11/spacex-and-facebook-are-on-a-race-to-globalize-the-internet/#614976767e4b, retrieved Nov. 14, 2017.