CITY OF SACRAMENTO

ITS

MASTER PLAN

FINAL | FEBRUARY 2019

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LIST OF ABBREVIATIONS

ATMS – Advanced Traffic Management System

ATP – Active Transportation Program

ATSPM – Automated Traffic Signal Performance Measures

AV – Autonomous Vehicle

AVL – Automatic Vehicle Location

CAD – Computer-Aided Dispatch

CCTV – Closed Circuit Television

CIP – Capital Improvement Program

CMS – Changeable Message Signs

CV – Connected Vehicle

EVP– Emergency Vehicle Preemption

GPS – Global Positioning System

HAR – Highway Advisory Radios

ITS – Intelligent Transportation Systems

O&M – Operations and Maintenance

RT – Sacramento Regional Transit

SACOG – Sacramento Area Council of Governments

SR – State Route

TOC – Traffic Operations Center

TMS – Traffic Management System

TSP – Transit Signal Priority

V2I – Vehicle-to-Infrastructure

V2X – Vehicle-to-Everything

1 EXECUTIVE SUMMARY

The **City of Sacramento** represents the largest transportation jurisdiction in the region. The City's transportation system plays an integral role facilitating the movement of people and goods between and through the surrounding cities. With transportation systems being asked to support more functions than ever before, agencies are leveraging technology and data solutions to help plan, build, maintain, and operate their future transportation networks.

This **ITS Master Plan** provides the framework necessary to improve mobility throughout the City's transportation network. This framework assists with prioritizing the following aspects: mobility, incident response, efficient maintenance, and cost savings. Intelligent Transportation System (ITS) investments are low-cost compared to capacity-related projects, such as expanding roads, and offer significant benefits to the transportation system and its users.

Vision

This City of Sacramento ITS Master Plan integrates technology, presenting the City's current and future needs with a focus on effective investments in transportation to improve system performance, safety, and sustainability. This Plan builds upon the City's existing ITS network and envisions a strategy to systematically implement innovative technologies to address the following overarching mission statement:

> To **improve system performance**, **safety**, **sustainability**, and **reliability** by **ensuring efficient investments** in regional smart transportation projects.

Goals and Objectives

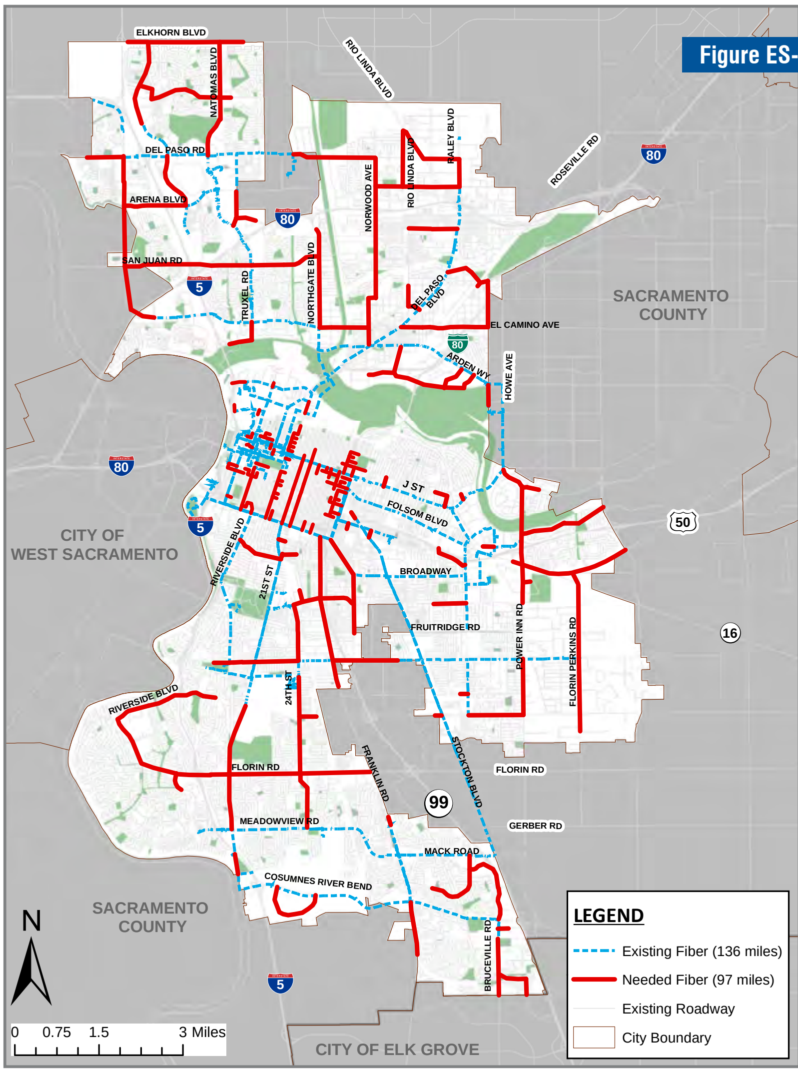
This Plan identifies projects that enable the City to expand its technology infrastructure, improve operations, and advance its institutions. The following objectives were defined for the Plan:

- ***Identify infrastructure and equipment needed*** *to build a comprehensive, modern, and reliable traffic signal system*
- ***Identify programmatic initiatives to*** *efficiently maintain and operate traffic signals and smart infrastructure while also planning for future technology*
- ***Develop strategies to incorporate*** *traffic performance measure data and analytics tools for operations analysis and project planning*
- ***Create a system*** *that allows for data-driven decision making*
- ***Develop a staffing plan to include*** *recommendations on staffing levels and skillsets*
- ***Improve City readiness*** *for connected vehicles and connected-infrastructure*
- ***Develop real-time*** *transportation data dashboard GUI*
- ***Address traffic signal*** *detection issues*
- ***Improve light rail interaction*** *on streets and at gated crossings*
- ***Integration of various transportation*** *data sets to provide a single data clearinghouse and real-time performance dashboard*

EXECUTIVE SUMMARY

State of the ITS

Figure ES-1 shows the type and locations of the City's existing and needed fiber optic infrastructure as part of the traffic signal communications network.



761	**TOTAL TRAFFIC SIGNALS**
14	**"HAWK" PEDESTRIAN HYBRID BEACONS**
44	**FLASHING BEACONS**
58%	**OF THESE ASSETS ARE CURRENTLY NETWORKED TO THE TRAFFIC OPERATIONS CENTER**

CABINETS NEAR END-OF-LIFE

CABINETS

house and protect ITS infrastructure at local intersections

CONTROLLERS NEAR END-OF-LIFE

CONTROLLERS

the computer or "brain" of a traffic signal at local intersections

SWITCHES END-OF-LIFE

NETWORK SWITCHES

allow ITS equipment and controllers to communicate over the fiber optic network

DETECTION END-OF-LIFE

VEHICLE DETECTION

detects vehicles at local intersections allowing efficient operation and traffic data collection

WITHOUT BBS

BATTERY BACKUP

emergency backup power for signals and ITS equipment in the event of a power outage

WITHOUT EVP

EMERGENCY VEHICLE PREEMPTION

provides emergency responders with green lights and stops conflicting traffic from obstructing their route

WITHOUT CCTV

TRAFFIC MONITORING

live video feeds at local intersections allowing monitoring of traffic and incidents from the TOC and City network

Needs Assessment

Sacramento's ITS needs were developed based on stakeholder input and were compiled and categorized by the following distinctions:

INFRASTRUCTURE (D)
field infrastructure, communications equipment, data, systems/software

OPERATIONAL (O)
operational improvement projects and processes, staffing

INSTITUTIONAL (I)
policies, agreements, funding/programming mechanisms, reporting/documenting, training

Strategies and Solutions

The following table summarizes the strategies to address the City's needs.

STRATEGY	NEEDS ADDRESSED	STRATEGY	NEEDS ADDRESSED
1A	Upgrade Communications Network - Install New Fiber-Optic Cable and Conduit	10	ATMS Upgrades and Add-ons
1B	Upgrade Communications Network - Replace Copper SIC with Fiber-Optic Cable	11	ITS Asset Management System
1C	Upgrade Communications Network - Install Wireless Communications at Isolated Intersections	12	ATSPM Deployment
2	Modernize Traffic Signal Controller Cabinets	13	Analytics Software and Performance Dashboard for Real-Time Operations Decision Making
3	Modernize Traffic Signal Controllers	14	Implement Citywide Traffic Signal Retiming Program
4A	Deploy Modern Advance Detection Equipment	15	Implement Transit Signal Priority
4B	Deploy Modern Stop Bar Detection Equipment	16	TOC Upgrade
4C	Pilot Technology for Advance Detection	17	Establish CAD System and TOC Connections for Automated Alerts and Notifications
5	Deploy CCTV Equipment	18	Establish Agency Network Security Policies and Procedures
6	Share CCTV Monitoring with Partner Agencies	19	Update Existing, and Develop New ITS Standards and Specification Materials
7	Traffic Signal and ITS Equipment Replacement Program	20	Improve Crash Data Collection and Analysis
8	Pilot Connected Vehicle Infrastructure	21	Traffic Signal Communications Network Documentation
9	Acquire and Integrate Third-Party Real-Time Traffic Operations Data	22	Deploy CMS

ITS Projects

A summary of implementation projects with associated costs is presented in Section 7.

Operations and Maintenance

To effectively operate and maintain the various project elements and projects identified in this Plan, the City must be adequately staffed and prepared to sustain the system after deployment. Operations and maintenance procedures are essential to define the appropriate staffing levels, training, operational processes, and maintenance levels necessary to sustain an effective system.

	RECOMMENDED STAFFING RATIOS*			CURRENT SACRAMENTO STAFFING RATIOS*
	SMALL CITIES	MEDIUM CITIES	LARGE CITIES	
ENGINEER/ OPERATIONS	25:1	50:1	75:1	91:1
MAINTENANCE/ TECHNICIAN	40:1	40:1	40:1	82:1

*Signal Assets : Staff

2 Introduction

The City of Sacramento has the largest transportation jurisdiction in the region. The City's transportation system plays an integral role facilitating the movement of people and goods between surrounding cities. With transportation systems expected to support more functions than ever before, agencies are leveraging technology and solutions to help plan, build, maintain, and operate their transportation networks.

This plan provides the City of Sacramento with the framework necessary to improve mobility throughout the transportation network. This framework will prioritize the following aspects: mobility, incident response, efficient maintenance, and cost savings. Intelligent Transportation System (ITS) investments are low-cost compared to capacity-related projects, such as expanding roads, and offer significant benefits to the broad transportation system and its users.

Transportation management is increasingly relying on technology, software, and applications. The future of transportation includes connected vehicles, autonomous vehicles, data-driven decision making and a focus on more effective operations and management of the transportation systems. ITS programs will continue to mature in their ability to actively manage traffic, incidents, events, and work zones.

There is an expectation from travelers that a City's transportation system can efficiently and safely move people. This plan provides the path forward to maximize the utility of the City's ITS program by developing a solid foundation of strategic and necessary infrastructure enhancements that will improve the City's operations and management capabilities.

3 Goals and Objectives

The City of Sacramento is well-positioned to advance transportation technology and embrace regional initiatives stemming from the area's diversity, economic activity, and evolving technological needs.

This City of Sacramento ITS Master Plan integrates technology, presenting the City's current and future needs with a focus on effective investments in transportation to improve system performance, safety, and sustainability. It builds upon the City's existing Intelligent Transportation Systems (ITS) network and envisions a strategy to systematically implement innovative technologies to address the following overarching mission statement:

MISSION STATEMENT

To improve system performance, safety, sustainability, and reliability by ensuring efficient investments in regional smart transportation projects.

3.1 Concept of Operations

The City of Sacramento, SACOG, and member-agencies have developed a Smart Region/ITS program that promotes coordination of operation and infrastructure of the transportation system between agency stakeholders. The program accommodates innovative technology to promote system-wide modernization, including reliable communications between stakeholders, sharing of real-time traffic data, improved transit operation, inclusion of active transportation, integrated corridor management, ITS maintenance strategies, improved central management systems, and traveler information services that provide real-time incident and traffic information.

The City of Sacramento has an influential role in the Region's transportation technology evolution, including an ability to effectively operate the transportation system in a proactive manner consistent with the City's and Region's priorities.

The City envisions a transportation system that uses technology to improve mobility and safety. Advancements in technology allows the City to maximize the existing right-of-way to effectively and safely move people. This system will be able to process substantial amounts of data effectively, allowing data driven decisions about where resources should be allocated. Additionally, data such as traffic counts, traffic signal performance measures, vehicle crashes, work orders, and customer complaints can be compiled in the system to deliver valuable performance metrics. This plan provides the framework to enable the City to achieve these overarching goals of a fully functional ITS.

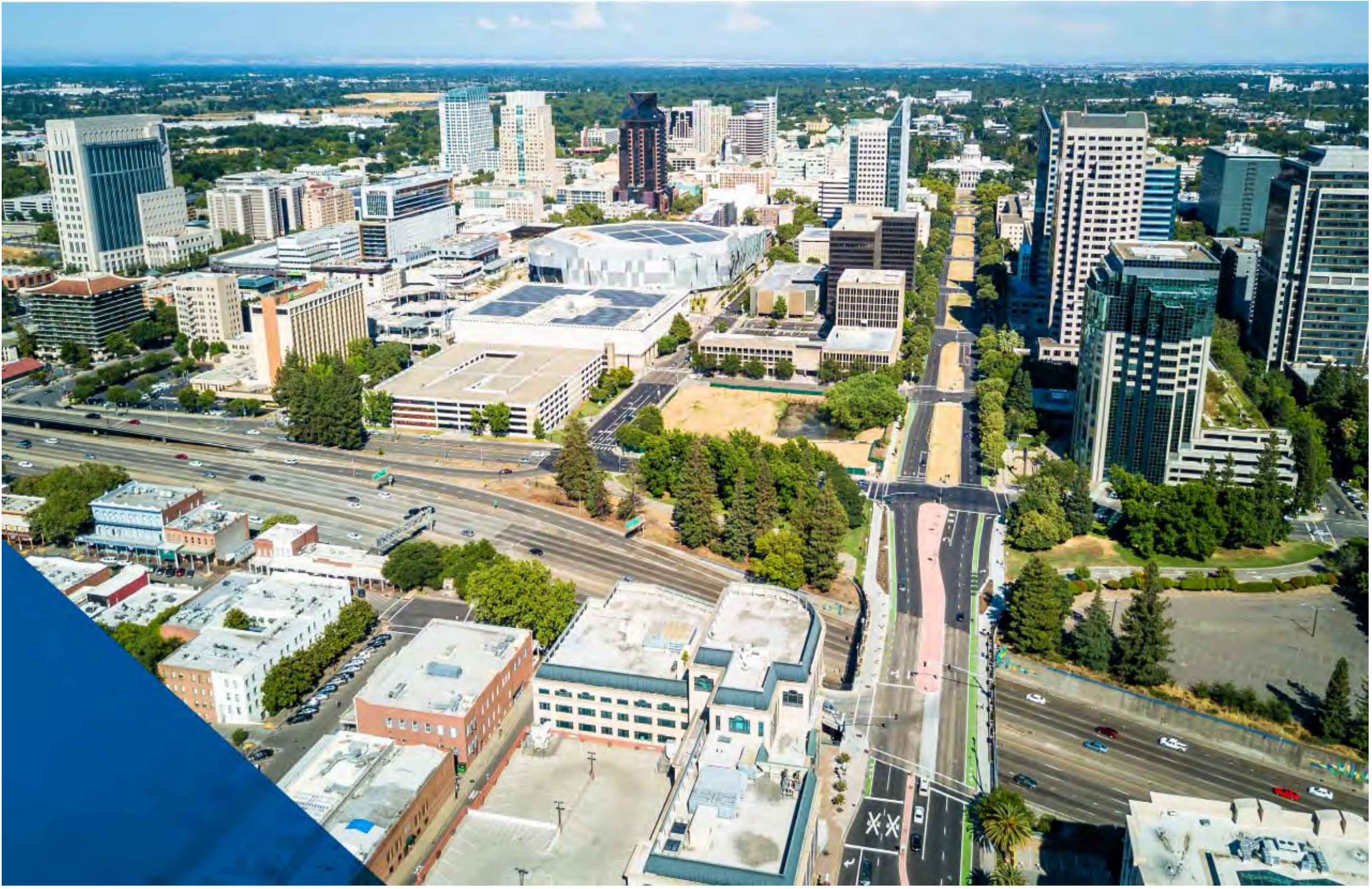
3.2 Local Goals and Objectives

The goal for this plan is to define technologies and set priorities for the implementation of technology to increase the safety, efficiency, and reliability of the City's transportation system. In addition, this plan develops a set of projects that enables the City of Sacramento to expand its technology infrastructure, improve operations, and advance its institutions while integrating with SACOG's Smart Region goals. The following objectives were defined for this Plan:

- ***Identify infrastructure and equipment*** *needed to build a comprehensive, modern, and reliable traffic signal system;*
- ***Identify new programs*** *to efficiently maintain and operate traffic signals and smart infrastructure while also planning for future technology. Such initiatives include:*
    - *Infrastructure Replacement Program*
    - *Preventative Maintenance Program*
    - *Traffic Signal Retiming Program*
    - *Technology Education and Piloting Program*
- ***Develop strategies*** *to incorporate traffic performance measure data and analytics tools for operations analysis and project planning;*
- ***Create a system*** *that allows for data-driven decision making;*

- ***Develop a staffing plan*** *to include recommendations on staffing levels and skillsets;*
- ***Improve City-readiness*** *for connected-vehicles and connected-infrastructure;*
- ***Develop real-time transportation data*** *dashboard GUI;*
- ***Address traffic signal*** *detection issues;*
- ***Improve light rail interaction*** *on streets and at gated crossings;*
- ***Integrate various transportation data sets*** *to provide a single data clearinghouse and real-time performance dashboard.*

These primary objectives are important considerations because they provide guidelines for identifying projects and creating performance measures to evaluate program efficacy.



4 Existing ITS Deployments

This section summarizes the existing transportation technology deployed in Sacramento. It is focused largely on the traffic signal equipment, the transportation communications network, and the City's Traffic Operations Center (TOC) and systems. In addition, current technology and data practices from an institutional level, including asset management and maintenance, design development, and data collection, are presented. A thorough understanding of existing conditions is essential in the identification of strategies and projects to address the City's needs.

4.1 Traffic Signals

Traffic signals consist of standards or poles, signal indications, conduit, conductors, controllers, and controller cabinets. To improve efficiency and operations, other technologies have become common at traffic signals. Examples of these include vehicle, pedestrian, and bicycle detection, emergency vehicle preemption, and traffic monitoring cameras.

As of the writing of this document, the City of Sacramento of owns, operates, and maintains 819 total signals, consisting of:

- ***761 traffic signals***
- ***14 high-intensity activated crosswalks (HAWK)***
- ***44 flashing beacons***

Figures 1 and **2** provide the type and locations of the City's existing traffic signal assets.

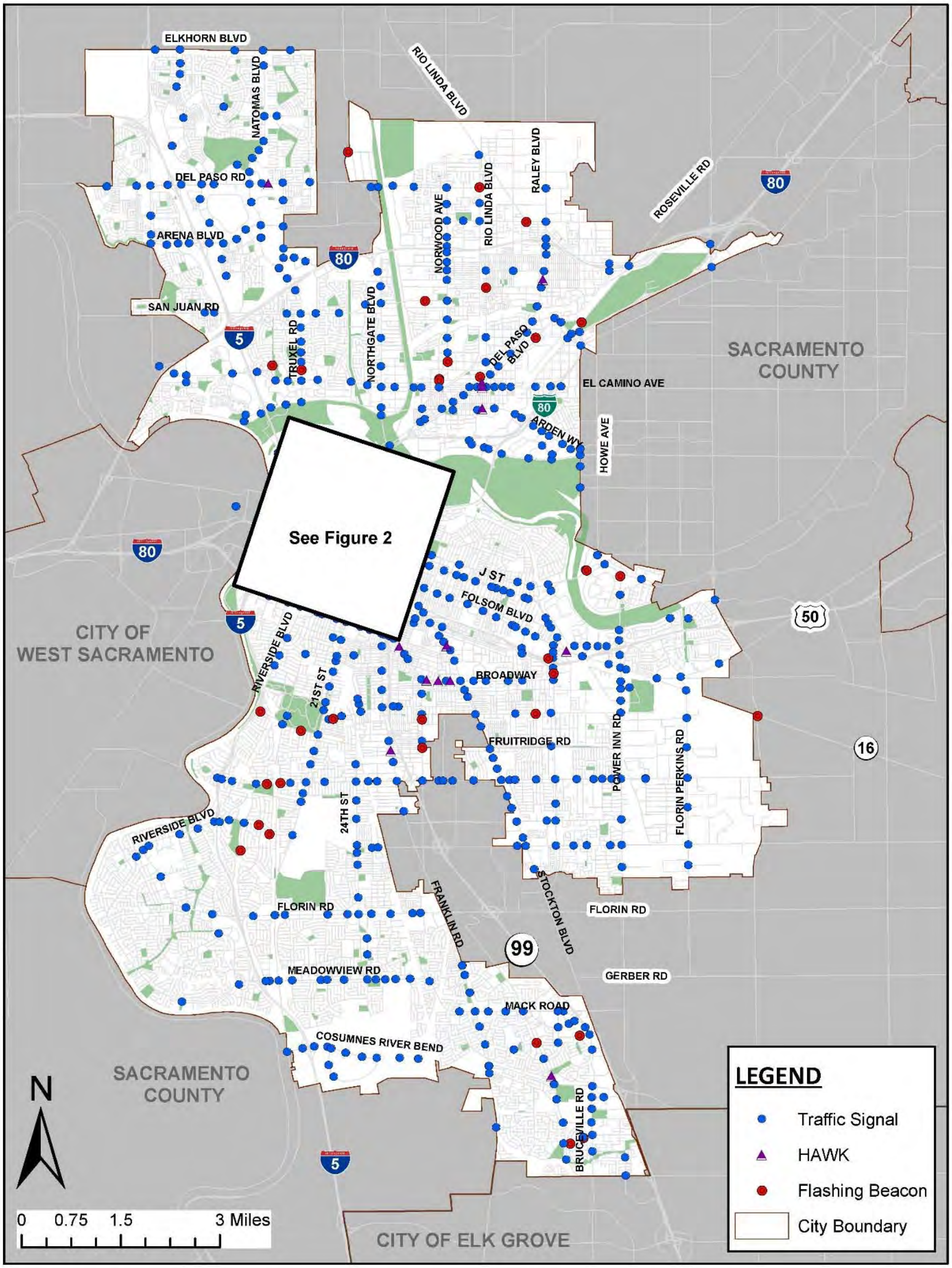


Figure 1 – City of Sacramento Traffic Signal Assets

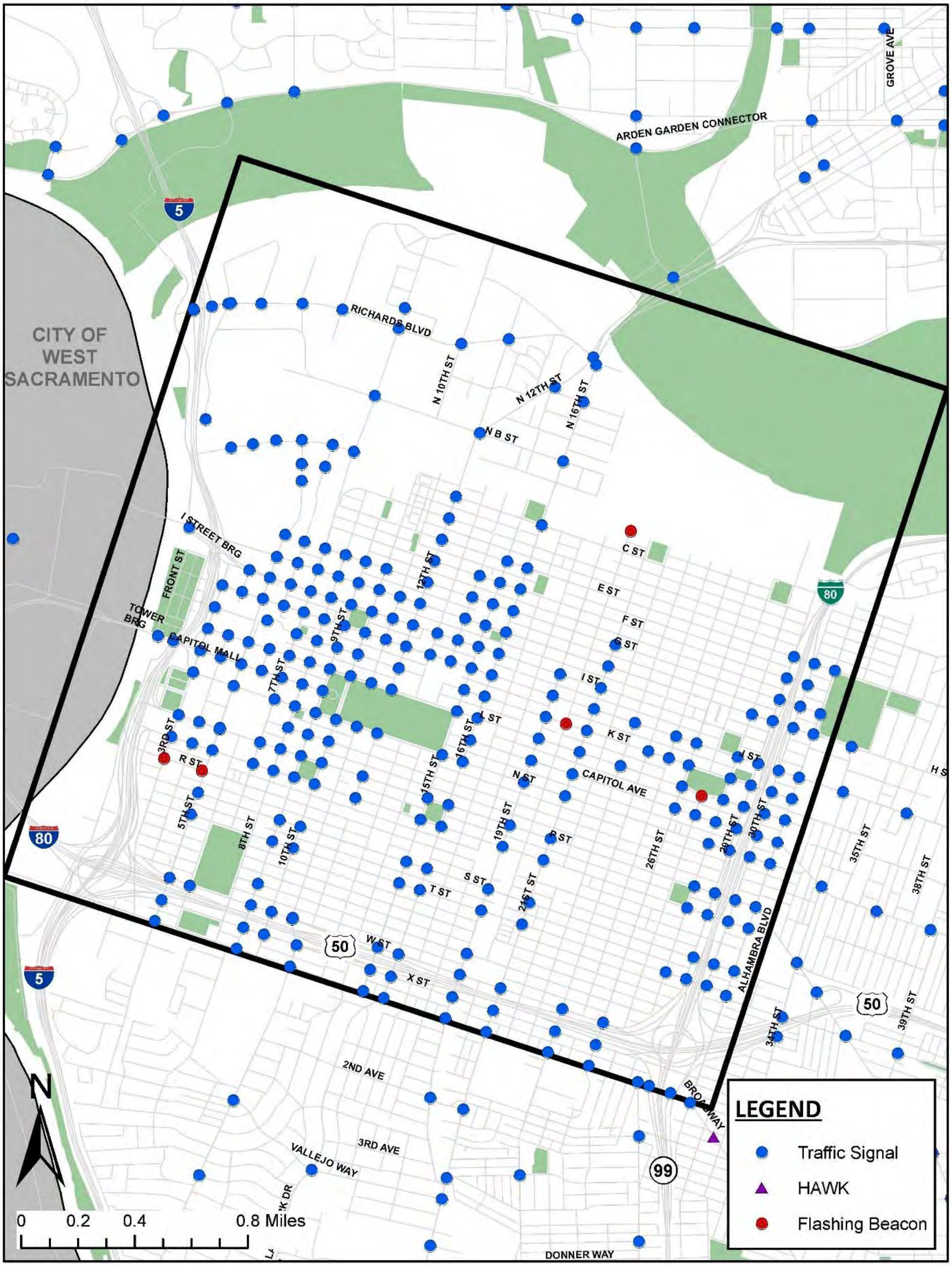


Figure 2 – City of Sacramento Traffic Signal Assets (CBD)

The following subsections give an overview of the state of traffic signal infrastructure equipment deployed in Sacramento.

Traffic Signal Controller Cabinets

Type 332L Cabinet

Traffic signal controller cabinets house and protect the electrical components necessary to operate and control a traffic signal. They also provide a means for each piece of equipment to communicate with each other. Advancements in traffic signal and communications standards require increased functionality from a traffic signal controller cabinet. Older controller cabinets offer little to no flexibility for technology upgrades.

A variety of traffic signal controller cabinets are deployed throughout the City of Sacramento ranging in age and model type. A sizable percentage of traffic signals have cabinets that have surpassed their usable life or are not capable of supporting replacement components or future traffic signal technology. Controller cabinets that don't meet current 332 or NEMA TS2 standards are considered end-of-life. These legacy cabinets represent nearly sixty percent of the City's total cabinet inventory.

Traffic Signal Controllers

Traffic signal controllers are the brain of a traffic signal and work to regulate the sequence and timing of signal indications. Outdated controllers limit the ability to deploy advanced technology and improve signal efficiency. A variety of traffic signal controllers are deployed throughout the City. Seventy percent of traffic signal controllers in the City have exceeded their anticipated useful life and should be replaced.

Vehicle Detection

Approximately sixty-five percent of the City's traffic signals have some form of vehicle detection. There is currently a mix of three detection types deployed in the City: inductive loops, video, and radar.

The City operates fixed-time, semi-actuated, and fully-actuated traffic signals. Most fixed-time signals are in the Central Business District (CBD) and do not have detection. Semi-actuated traffic signals have detection only deployed on the minor side streets and fully-actuated traffic signals have detection in all directions. When an intersection approach has detection, it consists of either stop bar detection or stop bar and advance detection. Detection is one of the most important components of a traffic signal, providing the abilty to operate efficiently and collect data.

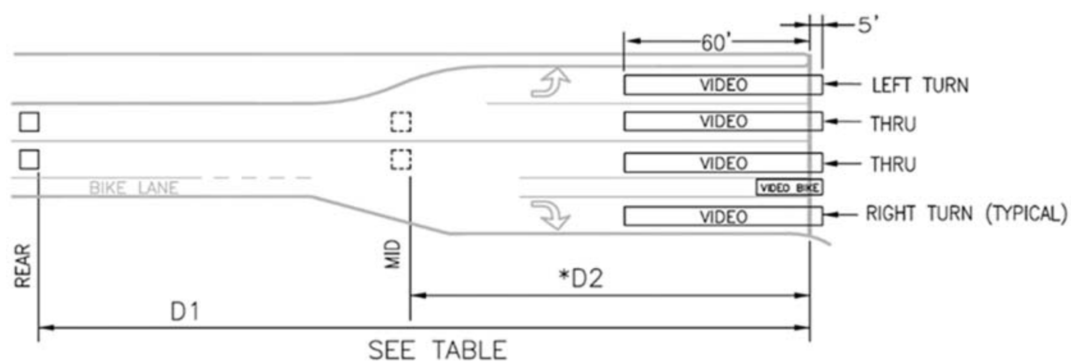
Advance Detection

Advance detection is placed between 175' and 405' prior to the intersection and is used to improve safety by providing dilemma zone protection. The City deploys advance signal detection at intersections which operate at speeds over 25 mph, however, much of the City's advance detection was placed to an older standard that does not provide dilemma zone protection to current standards. Reliable and accurate advance detection is the most valuable system for a traffic signal. In addition to improving safety and efficiency at the signal, advance detection can be utilized to collect corridor data such as vehicle speeds and flows. Many of the City's existing advance detection has all inductive loops connected on one channel, which does not allow the detection to collect useful traffic data. These installations are considered end-of-life.

The City has beta tested radar technology for advance detection, but they have been determined to not meet the City's needs. These systems are considered end-of-life.

The City is open to new technologies for advance detection, but the current City standard for advance detection is inductive loops.

The City has conducted tests of other technologies but have not yet determined any to be as accurate and reliable as loops. Testing of a new detection system is currently underway at one intersection in the City.



Excerpt from the City of Sacramento Standard Detector Layout

Stop Bar Detection

Stop bar detection is detection located near the intersection and allows the signal to know when vehicles are present and need a green indication. Four hundred and seventy (470) traffic signals employ in-pavement **inductive loop detection** for stop bar detection. Inductive loop technology is reliable for stop bar detection but offers limited flexibility for future modifications to intersections like geometric changes, deployment of advanced signal systems such as adaptive control or automated traffic signal performance measures. The City's current standard for stop bar detection is video detection. **Video detection** is used at 245 intersections, however many of these locations only have detection on one or two intersection approaches. Video detection is not installed in the pavement. Instead, virtual detection zones are programmed and can be modified at any time, even from the City's Traffic Operations Center (TOC) with good communications. The latest generation of video detection has significant improvements in accuracy, installation, programming and data collection. It also can provide reliable bicycle detection. The older generation systems are now considered end-of-life. Overall, accurate stop bar detection improves the operational efficiency of signalized intersections and serves as the primary source of traffic data in Sacramento.

Emergency Vehicle Preemption

Infrared EVP Detectors

Emergency vehicle preemption (EVP) equipment is used to detect the approach of emergency responders and provide their approach a green indication, thus dramatically improving emergency response times. Preemption systems require cooperation from both the traffic department and the fire department. Traffic signals require detection equipment and programming to operate preemption, and fire department vehicle must be equipped with emitters to notify the traffic signal of their approach. There are EVP systems deployed at 292 traffic signals throughout the City of Sacramento, of which, 135 are GPS-radio based systems, and 157 locations utilize infrared systems.

Battery Back-Up Systems

Redundant electrical design in the form of uninterruptable power supply (UPS) systems are becoming standard equipment at new traffic signals. Back-up power is especially important at grade-crossings where power outages can create very hazardous situations. Forty-four (44) signals in Sacramento have battery back-up systems (BBS) which provide continuous power to a traffic signal for several hours after power has been lost.

Traffic Monitoring Cameras

CCTV Camera

There are 122 existing closed-circuit television (CCTV) traffic monitoring cameras deployed at traffic signals in the City. **Appendix A, Exhibits A1** and **A2,** map the distribution of cameras in Sacramento. The majority are located in the downtown area and on primary arterials. Forty-four (44) of the City's 122 CCTV cameras have reached the end of their life expectancy and will likely require replacement soon.

4.2 Traffic Signal Communications Network

The City's traffic signal communications network allows for remote monitoring and modification to the City's traffic signals and traffic monitoring cameras. In addition to supporting traffic, the network is used by other City departments as well.

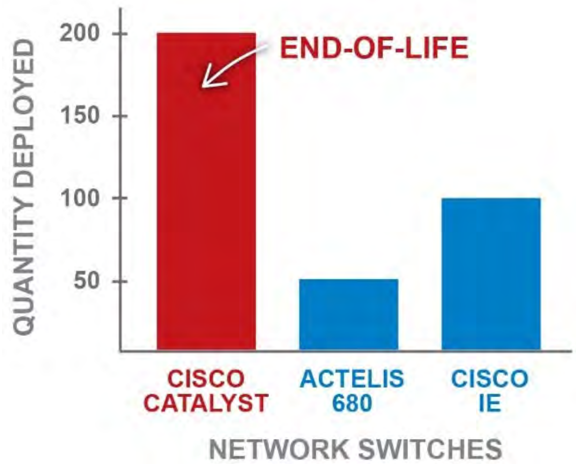
Communications Media and Conduit System

The traffic signal communications network consists of a mix of copper signal interconnect cable (SIC) and fiber-optic cable. SIC is a legacy technology which transmits serial communications over shielded copper conductors. Copper SIC was a cost-effective communications technology at one time, but even with updated communications equipment, copper SIC has limited speed, range, and bandwidth. There are approximately 98 miles of SIC distributed throughout the City.

There are approximately 136 miles of City-owned fiber throughout the City. **Appendix A, Exhibits A3** and **A4**, show the routing of fiber-optic cable and copper signal interconnect cable in the City's traffic signal communications network.

Communications Equipment

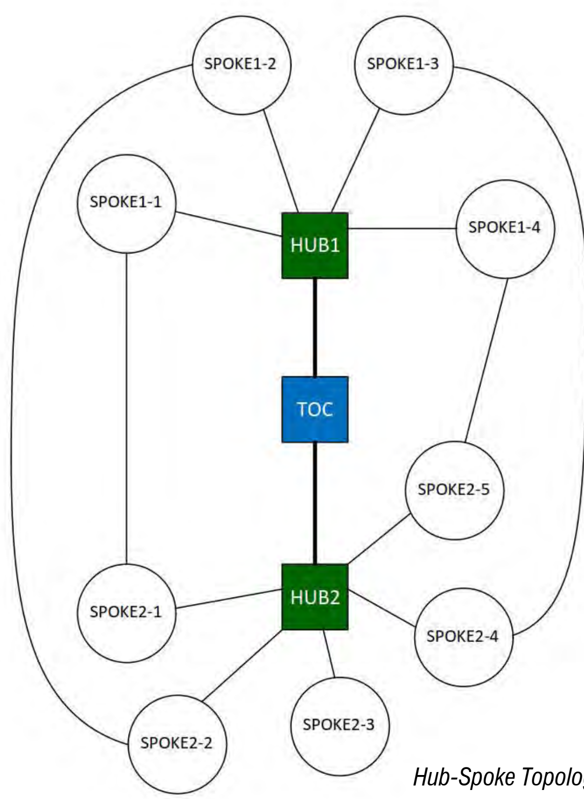
Network switches and communications hubs are deployed throughout the City to allow for IP-based communications across the traffic signal communications network. There are 324 network switches deployed at traffic signals and fiber communications hubs. Of these, approximately sixty percent have exceeded their anticipated useful life.



Communications Hubs

The City's traffic signal communications network is structured in a star topology, also known as a hub-spoke distribution, with some interconnected rings for redundancy. Communications hubs are distributed throughout the City. These communications hubs aggregate signal data in their area and transmit that data through back to the City's Traffic Operations Center. Communications equipment in the hub cabinets is environmentally-hardened and can support up to 60 intersections. Each fiber channel supports a maximum five intersections. The City currently has 12 communications hubs at the following locations:

1. Sacramento City Hall
2. 12th Street and I Street
3. Alhambra Boulevard and N Street
4. Broadway and 19th Street
5. 5th Street and Capitol Mall
6. Elvas Avenue and 65th Street
7. Stockton Boulevard and Broadway
8. Stockton Boulevard and Fruitridge Road
9. Cosumnes River Boulevard and Franklin Boulevard
10. Arden Way and Del Paso Boulevard
11. Truxel Road and Arena Boulevard
12. Railyards Boulevard and 5th Street



Hub-Spoke Topology

4.3 Traffic Operations Center

Overview and Existing Infrastructure

The City of Sacramento operates and monitors its transportation network from the its Traffic Operations Center (TOC) located in Sacramento City Hall. Staff monitor traffic signal operations and traffic conditions via three console workstations, two cubicle workstations, and a video wall display comprised of a 2 by 4 array of 55-inch monitors.

Behind the video wall, an equipment room houses video and networking equipment. The communication network, fed from a 144-strand fiber-optic trunk cable, links directly to this room. A Cisco Catalyst 4503-E core switch directs incoming signal controller and traffic monitoring information to the TOC data center and vice versa. Legacy traffic signal communications equipment is also located in the TOC and provides serial communications to legacy controllers. Other equipment at the TOC includes a Network Time Sensor (GPS clock) and several hub switches for the City's downtown traffic signal controllers. Additionally, there are several servers, both hardware and virtualized, that manage traffic signal communications, the CCTV camera system, windows active directory, and SQL databases. The TOC sytems are connected to a UPS and to City Hall's generator-based electrical back-up system.

Typical Traffic Operations Center (TOC) rendering showing Workstations and a Video Wall

The TOC has some inadequacies for a City of the size and profile of Sacramento. The TOC operates through a single core switch, creating a single point of failure that could take the entire system down. An additional core switch is recommended to provide network redundancy. The TOC is not set-up well to utilize collected traffic data and would benefit from systems to automate the input and streamline the use of data. Controller testing is an important task TOC staff perform. There isn't currently a convenient or efficient station for this to occur. A dedicated bench testing area, with connectivity to the ATMS is recommended. The TOC also lacks enough seating for current operations staff, which is likely to be exacerbated as more signals come online. The TOC is isolated from other transportation and City staff. The TOC and staff have functioned as the City's Emergency Operations Center (EOC). This role ads to the value of the TOC, but modification is necessary to provide this level of support without disrupting current staff job functions.

Traffic Operations Center (TOC) Connectivity and Systems

Four hundred and seventy-three (473) City traffic signals are connected to the TOC via the traffic signal communications network. However, 197 of these traffic signals communicate over serial and DSL connections, limiting their bandwidth and speed. Traffic signals connected to the TOC are managed by an Advanced Traffic Management System (ATMS). The City of Sacramento currently uses **TransSuite ATMS** software by TransCore. Traffic data is stored on separate City-owned servers. The system was last updated in 2017 and is compatible with the City's standard traffic signal controller models.

Traffic monitoring data from the CCTV camera network is compiled and maintained by **Milestone** software. An 860 MHz communications link exists in the TOC which connects the Police and Fire Departments to the TOC. The Police Department uses this direct link to video from the TOC in support of the City's Real-Time Crime Center (RTCC) used to aid officers in the management of large events and critical incidents throughout the City. This direct access to traffic department's monitoring cameras provides police officers with three-times the number of camera feeds they would otherwise have access to. Currently, City video is not available for public use.

Operations and Monitoring

Operators typically staff the TOC on weekdays between 7:00 A.M. and 9:00 A.M. and between 4:00 P.M. and 6:00 P.M.

4.4 Asset Management and Maintenance Systems

Transportation assets are managed internally on multiple platforms. A master inventory of signals and signal equipment is maintained with multiple spreadsheets. Inventory information is relatively complete for equipment such as controllers and vehicle detection but is incomplete or missing for details like the age of assets and communications networking information. Georeferenced locations of assets are hosted on different platforms including Google Earth and GIS shapefiles.

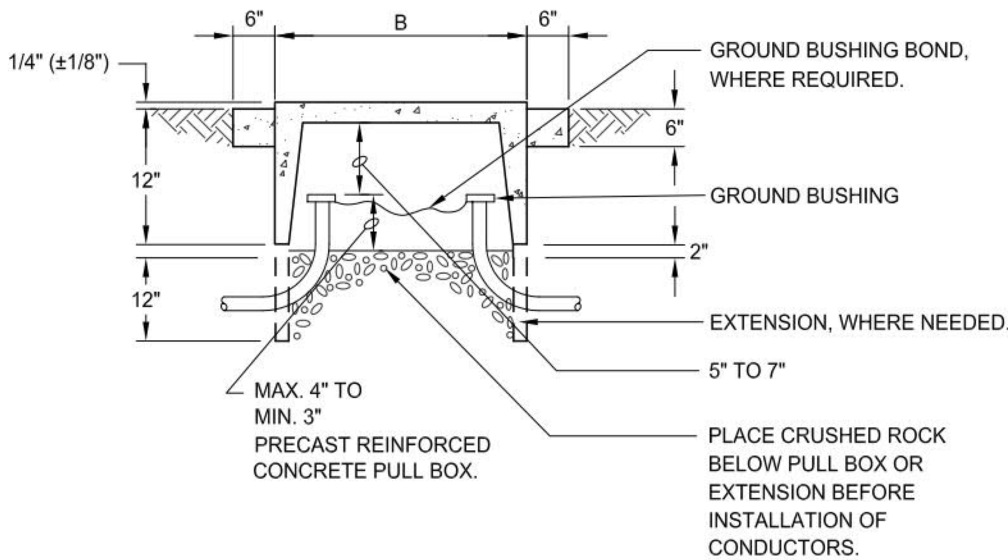
> "Asset Management tools and technologies may be helpful, but **the engagement of the workforce, the clarity of leadership, and the collaboration between different departments and functions are the real differentiators** of a leading asset management organization."
>
> *- Institute of Asset Management*

A work order system is in place; however, it is not linked to the asset inventory system or a public comment or complaint tracking system. This creates inefficiencies for staff as they must extract information from one source and document it in another, both of which may or may not have complete information.

Physical maintenance of the infrastructure is scheduled and completed by twenty staff. The maintenance department operates largely in a reactive capacity and primarily services grievances from the public. Routine and preventative maintenance of traffic signals, CCTV cameras, and other transportation assets is a lower priority and is rarely completed. The City of Sacramento does not have a traffic signal equipment replacement plan in place.

4.5 Design Standards

The City has adopted standard drawings for several traffic signal elements. These include street lighting, inductive loop detection, pedestrian push button posts, infrared emergency vehicle preemption, electrical conduit installation, and pull box installation. Standards for newer technology like video detection, communications equipment, fiber-optic cabling infrastructure, and CCTV cameras do not currently exist.



Excerpt from City of Sacramento Drawing No. E-210 "Concrete Pull Box"

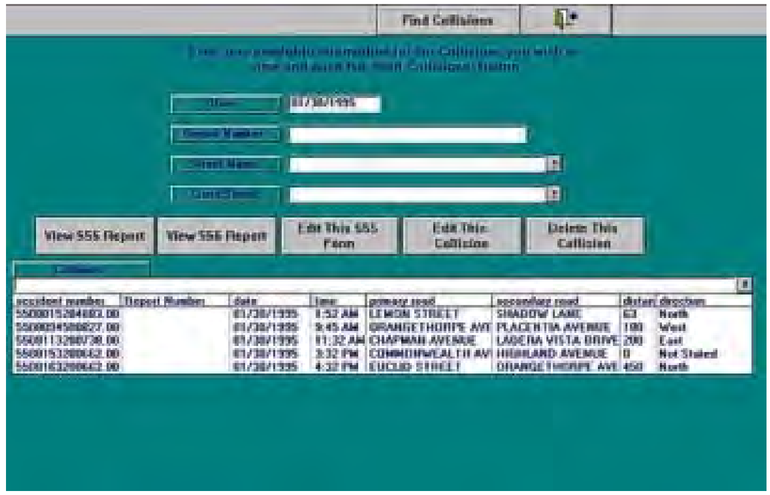
Standards hierarchy follows City of Sacramento standards and specifications and then the State of California standards and specifications.

4.6 Data Collection and Analysis

Sacramento collects data for various transportation applications. Traffic counts are an important metric in transportation planning and signal design. Historical traffic counts from City streets are manually entered and stored in a public, online clearinghouse. However, the City does not have an established program for routine collection of traffic counts, including counts for bicyclists and pedestrians, or a system in place that tracks and analyzes volume changes over time. Traffic count data is not integrated on any mapping platform.

The City has begun to collect and analyze high resolution traffic signal data. This data is collected and aggregated based on conditions at individual signals across the City, however, this is recent technology and the City is currently in beta testing phase at 10 locations. The data is stored in a database and is displayed using a free software package development by Utah DOT. Although the data is useful for operators, the system is not currently used by any other groups. This could be a result of the usability of the software or the limited size of the deployment.

Traffic collision history is a metric used for evaluating safety at intersections and corridors. The City utilizes **Crossroads** traffic collision database to manage its traffic collision data. The data is manually entered from police reports. Currently, police reports are only taken at collisions that involve injuries, leaving a large void in the total crash data information. Additionally, the available crash data is not mappable, reducing staffs' ability to analyze trends. The data is currently used to inform traffic safety studies or to supplement grant funding applications. Due to limited staff resources, collision data is rarely used in proactive ways such as identifying high-frequency collision locations or incident trends.



Crossroads Software Traffic Collision Database Screenshot

5 Needs Assessment

This section presents a summary of the needs identified for the City of Sacramento's intelligent transportation system. These needs were developed based on input from the City stakeholders and were compiled and categorized by the following distinctions:

- **Infrastructure (D)** – field infrastructure, communications equipment, data, systems/software
- **Operational (O)** – operational improvement projects and processes, staffing
- **Institutional (I)** – policies, agreements, funding/programming mechanisms, reporting/documenting, training

The needs associated under each of these categories are summarized below.

5.1 Infrastructure Needs

D1. There is a need to connect all traffic signals with fiber-optic cable - Only 276 of 775 traffic signals in the City are connected to the TOC via fiber-optic cable. High speed and high bandwidth communications is critical for the City to achieve its transportation goals.

D2. There is a need to monitor real-time traffic conditions - Sacramento does not have comprehensive or widespread device coverage to collect traffic data like speed, queues, and delay. Real-time data informs decision making allowing staff to react to actual conditions and make the most beneficial changes possible.

D3. There is a need to support active transportation - Investing in bicycle and pedestrian facilities increases safety for users and leads to a healthier public. Bicycle corridors in Sacramento do not have bicycle detection or bicycle signal timing to meet bicycle requirements per the updated MUTCD guidance.

D4. There is a need for redundancy in the traffic signal communications network - The communications network has minimal redundancy as it branches out from the central business district. Much of the system consists of isolated spurs rather than rings. In addition, the Traffic Operations Center is supported by a single core switch with no back-up. Failure of this switch would bring down the entire system.

D5. There is a need to replace aging traffic signal infrastructure - Many traffic signals are operating near end-of-life. Signals rely on equipment with outdated functional capabilities or are no longer supported by vendors. Old traffic signal poles are not structurally capable of supporting additional technology deployments.

D6. There is a need for adequate communications bandwidth - Half of the City's communications network relies on copper signal interconnect cable which is limiting in capacity for future technology support and the City's data needs.

D7. There is a need for additional communication hubs - There is a need to deploy more communications hubs to support the transportation communications system. Each hub supports up to sixty traffic signals. Additonal hubs are necessary for the City to expand its system.

D8. There is a need for an advanced asset management and maintenance system - The transportation division lacks a modern and reliable asset inventory system. Assets are managed manually using spreadsheets not tied to a maintenance or replacement tracking system. Inventory and maintenance of new deployments is an integral component for a successful ITS.

D9. There is a need for central system management of tools and data to support operations - The central system (ATMS) lacks functionality required by TOC operators and needs updates and add-ons to address the City's needs.

D10. There is a need to collect, analyze, and use signal performance measures - There is currently a lack of performance measurement and analysis capabilities. Performance measures are used to evaluate the effectiveness of the City's projects and programs.

D11. There is a need for spare equipment inventory to prevent system and signal downtime - The inventory of spare ITS equipment is unknown or non-existent. This does not allow for proper programming of replacement needs causing maintenance staff to operate primarily in a reactionary capacity.

D12. There is a need for timely emergency notifications - The City does not have automated emergency notifications capabilities which greatly reduce timely responsiveness.

D13. There is a need to reduce the impact of light rail preemption on traffic mobility - Light rail preemption in the downtown grid and on corridors adjacent to light rail lines knocks the signal system out of coordination, adversely affecting vehicular traffic.

D14. There is a need to share data between agencies that share congested corridors - The City shares numerous major corridors with adjacent jurisdictions and there is a lack of information sharing across jurisdictions to provide for the most efficient operations.

D15. There is a need to utilize data (crash records, traffic counts, corridors speeds, congestion data, work orders) to support planning purposes - The amount of data currently collected is limited, and the use of that data is also limited. The City's current data systems and tools are not user-friendly and are very labor intensive to make use of. Modern and integrated systems will aid the City in the collection and application of traffic data allowing informed decisions regarding the transportation system.

D16. There is a need for Connected Vehicle (CV) technology readiness - Infrastructure and systems are not currently able to support CV deployments or data.

D17. There is a need for a programmatic citywide traffic signal retiming plan - Signal retiming is not surveyed or updated at regular intervals. By developing a retiming strategy and utilizing modern technology, signal timing can be improved continually instead of every few years.

D18. There is a need to improve advance vehicle detection - New advance detection technology can more effectively prevent dilemma zone conflicts and improve signal operation efficiency. Modern advance detection can also be utilized to collect corridor data such as vehicle speeds and flows.

5.2 Operational Needs

O1. There is a need for improvements to the Traffic Operations Center (TOC) - The TOC is undersized for a City the size of Sacramento and the staff that operates it. There is not enough workstation space for the recommended staff levels, and there is no designated area to perform bench testing of controllers.

O2. There is a need for additional traffic operations staff - There is a lack of sufficient staffing to support traffic operations functions, limiting the staff to operating the City's ITS responsively rather than proactively.

O3. There is a need to standardize operating and maintenance procedures for ITS - Maintenance is performed at random intervals and usually initiated by public complaints. There are inconsistent procedures for operations and maintenance of ITS.

O4. There is a need to improve operations downtown, including light rail operation - Downtown Sacramento is not operationally efficient due to the various, uncoordinated modes of traffic competing for right-of-way and priority.

5.3 Institutional Needs

I1. There is a need for a high security and tamper-proof network - The City's assets are vulnerable to basic cyber-attacks which leave the entire system exposed. Edge switches dispersed at traffic signals across the City provide potential access points into the City's network.

I2. There is a need for Connected Vehicle (CV) technology policy - City policies and codes currently do not support or address CV.

I3. There is a need for a reliable funding strategy - The City lacks reliable funding mechanisms to support Smart City, Smart Region, and ITS initiatives, limiting its ability to address challenges.

I4. There is a need for ITS standards - Deployment of a wide variety of ITS devices and subsystems has created system integration, maintenance, and system management challenges. Standardizing the City's ITS and deploying consistently from now forward will eventually alleviate these challenges.

I5. There is a need to promote and support Vision Zero - There is a lack of intentional strategic investments in ITS to support Vision Zero initiatives.

The strategies to address these needs are discussed in further detail in the next section.

6 Strategies and Solutions

This section presents strategies to address the City's needs presented in the previous section. Some of these strategies are meant to be standalone solutions to City needs while others are most valuable combined with other strategies and assembled into more complex projects.

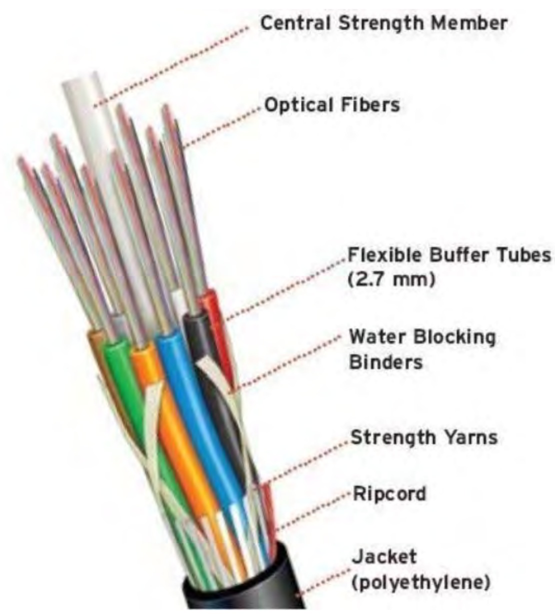
Strategy #1A

Upgrade Communications Network - Install New Fiber-Optic Cable and Conduit

Description – Eliminate communications gaps that exist along key corridors. Utilize fiber-optic cable to achieve high bandwidth, high speed, reliable communications coverage. Connect to ITS devices and traffic signals along the key corridors.

Scope/Limits – Install fiber-optic cable and new communications conduit, as necessary, to City traffic signals not currently connected. Fiber trunk cables should be installed where multiple traffic signals (more than five) will be connected. Distribution, or branch, cables should be installed to connect isolated intersections (less than five). This strategy includes connecting all signals on these segments to the TOC by installing fiber equipment in traffic signal controller cabinets. All necessary splicing and testing to accomplish this strategy is included. Conduit for fiber-optic cable should be installed as a minimum of two 2” conduits, providing for future expansion.

Fiber-Optic Cable – New fiber-optic network installations should consist of two types of fiber cable, trunk cable (typically 48, 96, and 144-strand single mode fiber-optic cable) and distribution cable (typically 12 or 24-strand single mode fiber-optic cable). The cable sizes recommended within this Plan are anticipated to be sufficient for the anticipated communication needs of the City, but may be increased or decreased depending on cost, procurement, and timeline for any given corridor or segment of new fiber-optic cable to be installed.



Fiber-Optic Cable Components

Trunk cables are recommended to be 144-strand cables, to allow for expansion of the system. Many cities and counties choose to allocate fiber to share with City departments and partner agencies as well, and extra capacity will allow for these possibilities in the future. The distribution cables, also referred to as branch cables, are typically spliced to the trunk cable. They are recommended to be 12 or 24-strand cables. Like the larger trunk cables, sufficiently sized branch cables will enable additional connections in the future.

Fiber-Optic Cable Routing - The routing of the fiber-optic cable in the communications system should form a series of “rings,” also referred to as a ring topology, with main corridors handling most of the trunk cable rings to provide redundancy in the network. This is essential in the event of a severed trunk cable or equipment failure to keep the network online. A complete ring will offer an alternate route for the communication of intersections or equipment on either side of the break.

Strategy #1B

Upgrade Communications Network - Replace Copper SIC with Fiber-Optic Cable

Description – Replace existing copper signal interconnect cables with fiber-optic cable to achieve high bandwidth, high speed, reliable communications coverage. Connect to ITS devices and traffic signals along the corridors.

Scope/Limits – 98 miles of existing legacy copper SIC will be replaced with fiber-optic cable. The existing signal interconnect conduit is assumed to support the switchover to fiber cabling, though pull boxes and conduit sweeps will likely require modification to make them fiber-ready. This strategy includes connecting all signals on these segments to the TOC by installing fiber equipment in traffic signal controller cabinets. All necessary splicing and testing to accomplish this strategy is included.

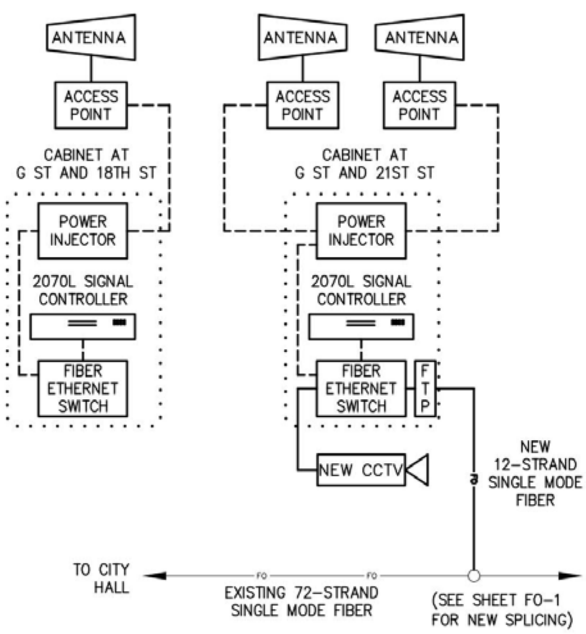
Strategy #1C

Upgrade Communications Network - Install Wireless Communications at Isolated Intersections

Description – Eliminate communications gaps that exist along key corridors. Utilize wireless communications to connect remote traffic signals and ITS devices to the communications network without the expending the high cost of fiber infrastructure.

Scope/Limits – Install and configure wireless communications equipment at remote City traffic signals and ITS devices not currently connected. Remote locations should be connected via wireless technology to the nearest, or most appropriate, fiber access-point. From there, data will be sent to the TOC over the existing fiber-optic network.

Wireless Communications – Wireless systems offer moderate bandwidth at distances of up to 20 miles, however, they require unobstructed lines of sight between antennas to achieve the best results. They are also susceptible to interference and require more maintenance than underground cable systems. Although they cannot match in speed and capacity of fiber-optic interconnect, this alternative can provide satisfactory communications to meet short-term needs at a very low cost. Inexpensive wireless options available to the City include, leased wireless (cellular) technology or City-procured wireless technology that uses radios and antennas mounted on traffic signal poles.



The leased wireless option requires the procurement of services from a cellular provider with service level agreements on the performance of the wireless connection (e.g., bandwidth). For the City-owned wireless option, there are licensed and unlicensed radio spectrum that can be used. It is common for traffic signal and ITS networks to utilize the unlicensed spectrum, particularly the frequencies in the ISM (Industrial, Scientific and Medical) bands.

Strategy #2

Modernize Traffic Signal Controller Cabinets

Description – Upgrade traffic signal controller cabinets to support modern equipment with communications and monitoring capabilities. New controller cabinets should be at a minimum NEMA TS-2 Type 1, 332L, 332LX, or ATC cabinets, depending on the installation location, intersection characteristics, and controller type. Type 332 cabinets are used in the central business district (CBD) and NEMA Type R cabinets are utilized elsewhere.

Scope/Limits – Approximately sixty percent of the City's controller cabinets are legacy or end-of-life.

Strategy #3

Modernize Traffic Signal Controllers

Description – Upgrade traffic signal controllers to provide open architecture for a wide variety or ITS applications. New controllers should support IP communications, provide high-resolution controller data, capable of dynamic management of signal phases. Controllers should be Linux-based NEMA ATC, 2070 ATC, 2070LX, or comparable.

Scope/Limits – There are 581 traffic signals operating with legacy controllers throughout the City. Approximately, 150 of these are within the CBD and are programmed to be replaced through a grant program. The City should replace as many controllers as feasible to attempt to catch-up and build a solid foundation of modern controllers.

Strategy #4A

Deploy Modern Advance Detection Equipment

Description – Deploy new modern advance detection equipment at signalized intersection locations currently operating with substandard or no advance detection. The detection device should be able to detect vehicles, speed, and predict vehicle arrival at the intersection to support dynamic split adjustments.

Scope/Limits – Within the City, 247 traffic signals are operating by way of vehicle loop detection and 297 signals have no detection at all. Almost all signals within the downtown grid have no detection. With the introduction of bicycle lanes and corridors throughout the City, modern detection must have the ability to detect and discriminate bicycles from other vehicles on the road. The systems will have the ability to collect real-time turning movement counts for planning purposes and signal timing as well as be the ability to collect traffic operations data such as speed and queues which will allow for ATSPM analysis.

Advance Detection – The City deploys advance signal detection at intersections which operate at speeds greater than 25 miles per hour. The current City standard for advance detection is inductive loops. Loops are accurate and reliable for advance detection and should continue to be deployed at this juncture. Loops, however, are limited in their benefit to future applications like ATSPMs and dynamic split control. The City has conducted tests of other technologies but have not yet been satisfied with them. The City should continue testing advance radar detection systems until they find an agreeable technology. A radar system with trajectory tracking and user discrimination capability will provide more useful data for the City than inductive loops.

Strategy #4B

Deploy Modern Stop Bar Detection Equipment

Description – Deploy modern video detection systems at signalized intersection locations currently operating with inductive loop detection or no detection. Accurate stop bar detection improves operational efficiency of signalized intersections and serves as the primary source of traffic data in Sacramento. Video detection systems require cameras to be mounted on traffic signal poles such that they have a view of all legs of the intersection. The system should be able to discriminate between vehicles, bicycles, and pedestrians. Video detection will have the ability to collect turning movement counts to support signal timing development, and act as traffic monitoring cameras if none exist at the intersection.

Scope/Limits – Four hundred and seventy (470) traffic signals employ in-pavement inductive loop detection and another 297 traffic signals have no detection. The City should plan to install video detection at as many signals as feasible, but 20 traffic signals per year should be an attainable goal. This strategy entails the procurement and installation of detection cameras or sensors and cabling, and the configuration of camera control units and virtual detection zones.

Video Detection – Video detection systems are non-intrusive systems that utilize programmable, virtual detection zones that can be adapted to changing conditions and patterns. They can be used to support emerging systems such as automated traffic signal performance measures (ATSPMs), and alternate timing modes such as dynamic all-red, and bicycle signal timing.

Strategy #4C

Pilot Technology for Advance Detection

Description – Identify and deploy innovative advance detection equipment at signalized intersections in the City as part of a pilot program. The City will use the results of the pilot program to consider implementing a new City standard for advance detection at traffic signals.

Scope/Limits – Advance detection technology should be deployed at up to ten (10) signalized intersection in the City. The intersection should have communications in place to allow for remote monitoring of the detection technology. The detection devices should be able to detect vehicles, speed, and predict vehicle arrival at the intersection, at a minimum. Detection devices should be tested for a minimum of six months and through varying weather conditions.

Strategy #5

Deploy CCTV Equipment

Description – Deploy new CCTV equipment at signalized intersection locations that currently do not have traffic monitoring capabilities. CCTV deployment requires cameras to be mounted on traffic signal or street lighting poles and connected to the traffic signal communications network in the controller cabinets. CCTV video provides real-time streaming video allowing traffic operations staff to view road network conditions and to share information about real-time conditions with partner departments, such as public safety, that may need to respond to an incident or event. The new CCTV will need to be integrated into the City's video management system for viewing and control.

Scope/Limits – Sacramento has 121 CCTV cameras deployed throughout the City. New CCTV cameras will be deployed at all intersections without monitoring in place and with connection to the traffic signal communications network. Priority will be given to locations on primary corridors and intersections with high incident rates. CCTV cameras will be IP-based, high definition, pan-tilt-zoom, with WDR (Wide Dynamic Range) functionality. The City should plan to deploy approximately 60 CCTV cameras per year to establish monitoring capabilities at all intersections within 10 years.

Strategy #6

Share CCTV Monitoring with Partner Agencies

Description – Utilizing a robust communications center-to-center network between agencies, CCTV streaming video images should be shared between regional agencies. Shared control of CCTV may not be desirable nor feasible but could be allowed through this center-to-center asset viewing capability.

Scope/Limits – A network will be set up on a regional basis to share CCTV imagery between agencies.

Strategy #7

Traffic Signal and ITS Equipment Replacement Program

Description – An equipment replacement program is a proactive approach to operating, maintaining, and budgeting the routine replacement of traffic signal and ITS equipment. The replacement program will establish policies, procedures, and budgets for the systematic replacement of failed and end-of-life equipment. Replacing out-of-date and unreliable equipment is a critical component in developing a comprehensive, modern and reliable traffic signal system. While this Plan focuses on technology infrastructure at traffic signals such as controllers, communications equipment, CCTV, and detection systems, other traffic infrastructure, such as traffic signal poles, should be included in the replacement program.

Scope/Limits – The City will develop a traffic signal and ITS equipment replacement program that promotes regular replacement of outdated equipment and establishes spare inventory to efficiently replace failed equipment. The program will establish equipment replacement rates, spare equipment guidelines, extended budgets, and define staff responsibilities.

End-of-Life Equipment Replacement – The City should program the costs associated with replacing traffic signal and ITS equipment. As time passes, overall performance of equipment will degrade and/or fail as it reaches the end of its useful service life. When this occurs, devices will need to be replaced. It should be expected that some assets will fail early, and others may continue to function past their average life expectancy.

Excluding assets that can be replaced under warranty, the City should plan for a certain number of assets to fail each year and should expect that number to increase over time. Eventually, the total number of failures per year for an asset type will level off at a number that is approximately equal to the total number of devices of a particular asset type divided by the average life expectancy of that asset:

Average asset failures per year = total number of assets / asset life expectancy

Considering the installation dates of existing ITS equipment, and the expected lifespan of each device, the City should initiate a replacement strategy to proactively procure and upgrade/replace legacy equipment. The following replacement quantities should be a starting point and are based on the end-of-life ITS equipment devices currently operating in Sacramento. Once additional ITS devices are installed and connected to the network these rates should be increased proportionally.

- *Replace 20 Cabinets per year*
- *Replace 50 Controllers per year*
- *Replace 10 CCTV cameras per year*
- *Replace 20 Video Detection Units per year*
- *Replace 25 communication switches (intersection) per year*

For other traffic signal equipment, opportunities for replacement and upgrades should be evaluated in conjunction with the recommended corridor enhancement projects recommended as a part of this Plan.

Spare Inventory – An inventory of replacement devices, equipment, and spare parts should always be maintained to allow for timely replacements or repairs of failed or damaged equipment. The replacement program should support a spare inventory of approximately ten percent of the total number of traffic signal and ITS devices. The City should maintain two to three percent of the total deployment for adequate spare devices to have on hand for maintenance purposes, plus an open Purchase Order for seven to eight percent (totaling 10 percent total).

Strategy #8

Pilot Connected Vehicle Infrastructure

Description – Deploy CV equipment (5G) at signalized intersections. This strategy would initiate a pilot program of key corridors that supports City-owned CV technology and would require procuring CV equipment to be installed at signalized intersections along priority corridors. Expansions to this pilot program would be assumed after the pilot project completion. This strategy does not include the push of specific CV data to vehicles using the system, but rather making the CV infrastructure available for agencies or the region to utilize when CV software and data are more robust and available.

Scope/Limits – The City of Sacramento will pilot the procurement and implementation of 5G equipment as part of a long-range vision to deploy vehicle-to-infrastructure technology at all signals. The City should evaluate this technology at various locations throughout the city to allow for a thorough evaluation of applications and capabilities. Pilot locations should target areas that serve transit and active-transportation modes as well as different roadway operations such as in the CBD and major arterials.

Connected Vehicles – Connected Vehicle (CV) technology will enable cars, trucks, buses, and other vehicles to “talk” to each other, to infrastructure (traffic signals), and with other road users (pedestrians with compatible smartphones) using built-in, or add-on devices that continuously share important safety and mobility information. CV technology enables communications among vehicles, infrastructure, and personal communications devices operated by passengers, pedestrians, bicyclists, or other road users.

The use of connected vehicles and technology will provide several benefits to the City. This includes benefits in the areas of Safety, Mobility and the Environment. More specifically, connected vehicles provide the following benefits:

Safety

- *Reductions in crashes with combinations of safety and road weather applications including:*
- *Red Light Violation Warning and Pedestrian in Signalized Crosswalk Warnings*
- *Grade Crossing Warnings*
- *Curve Speed Warnings*
- *Weather Warnings*

Mobility

- *Applications that are effective in prioritizing signal timing and reducing travel time and overall delay with the following:*
- *Combinations of signal control applications such as Intelligent Traffic Signal Systems, Transit Signal Priority and Freight Signal Priority*
- *The Incident Scene Pre-Arrival Staging Guidance for Emergency Responders*
- *Cooperative adaptive cruise control and speed harmonization*

Environmental

- *Applications have potential congestion and lane management capabilities and can reduce fuel consumption and emissions through:*
- *Optimized signal operations and freeway lane management applications*
- *Low Emissions Zone applications*

Strategy #9

Acquire and Integrate Third-Party Real-Time Traffic Operations Data

Description – Acquisition of third-party data on a regional level to collect and distribute real-time data on the transportation network to utilize for real-time operations improvements. The system must be integrated into the City’s existing ATMS in a way that ensures the data is useful and provides actionable information. This strategy will be leveraged by the City to use this third-party data for real-time operational decision-making purposes.

Scope/Limits – The City will receive third-party real-time traffic data, such as origin-destination (OD) and travel time, to monitor conditions and evaluate travel characteristics for planning and operational purposes. Sacramento will receive a local subscription as part of the master Regional subscription.

Strategy #10

ATMS Upgrades and Add-ons

Description – Upgrade the City's Advanced Traffic Management System (ATMS) to incorporate new functionality. Additional data to incorporate into ATMS upgrade includes, real-time volume and delay, emergency vehicle activations, transit signal priority logs, adaptive signal performance measures, emergency notifications, weather notifications, and equipment maintenance status and alerts. Additional modules may be needed to support travel time devices and connected vehicle technology, among others.

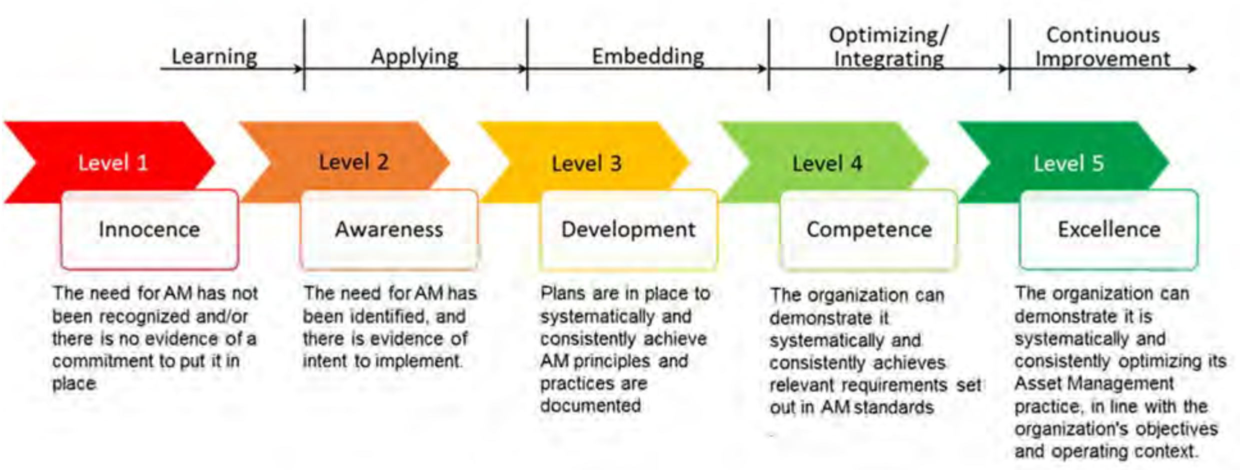
Scope/Limits – Procurement of ATMS add-on modules and software updates to systems to incorporate new functionality including modules with the following capabilities:

- *Adaptive Signal Control*
- *Asset Management*
- *Data-to-Web*
- *ATSPM*
- *EVP*
- *TSP*
- *Data Recovery*
- *CCTV*

Strategy #11

ITS Asset Management System

Description – Procure and implement an asset management system. Includes software, installation, integration, and data migration and population. In addition to the procurement of the physical system, the City should develop an asset management program with policies that ensure continuous updating and monitoring of the City's ITS assets. This strategy will require additional staffing or staff time for the development, administration, and maintenance of the program.



The Asset Management Maturity Scale

Scope/Limits – The City will transition the collection, storage, and analysis of assets from existing spreadsheet software methods to a new comprehensive, secure, and georeferenced asset manager.

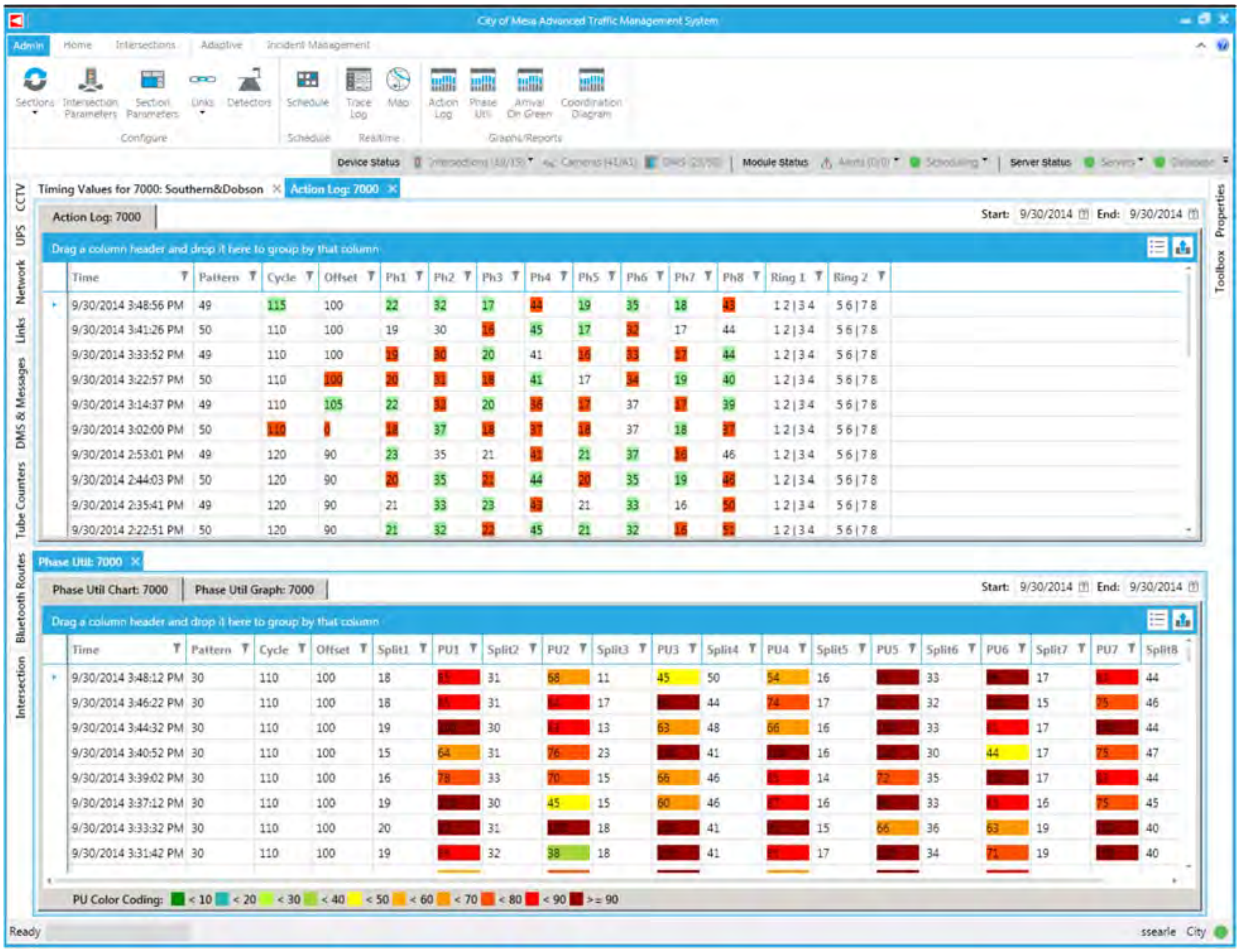
Once a desired platform is selected, staff will need to program time to transition all assets into the new management system. The software will have standardized and pre-populated fields to ensure data is categorized in simple and meaningful groups. The system should have the ability for staff to create, track, and close maintenance orders or be compatible with a separate system that has this functionality. In addition, the system should be capable of tracking and scheduling preventative maintenance on user-defined intervals. The system should store equipment details including make, model, age, install date, traffic count data, electronic as-builts and record drawings, signal timing data, photographs, and maintenance and operations notes.

Strategy #12

ATSPM Deployment

Description – Implement an Automated Traffic Signal Performance Measure (ATSPM) system. ATSPMs consist of high-resolution data-logging capability added to existing traffic signal infrastructure and data analysis techniques. This provides the information needed to proactively identify and correct deficiencies, improve signal timing and coordination, and collect ongoing performance measures to demonstrate the effectiveness of optimization efforts.

Scope/Limits – Plan, procure, implement and integrate an ATSPM system at City traffic signals. ATSPM systems require four components: advanced high-resolution traffic signal controllers with built-in data loggers, accurate vehicle detection, reliable communications to traffic signals, and an ATSPM server and software. An advanced controller collects accurate data from the detection system and combines it with signal operations information. This data is sent over the traffic signal communications network to the ATSPM server and input to the software. The software can store the detection and controller data in a database and includes algorithms to analyze the data. The software should have the necessary graphic user interface (GUI) to allow efficient use of and distribution of the data. Strategies #1, #3, and #5 focus on implementing communications, controllers, and detection. This strategy focuses on developing City standards, policies, and procedures for ATSPM and implementing and integrating the system itself. An important consideration is, the outputs of any ATSPM system are only as good as the data inputs. The most important inputs for the traffic signal system are advance and stop bar vehicle detection. In order to develop an effective ATSPM system, expanding the City's quantity of reliable and accurate vehicle detection should be a top priority.

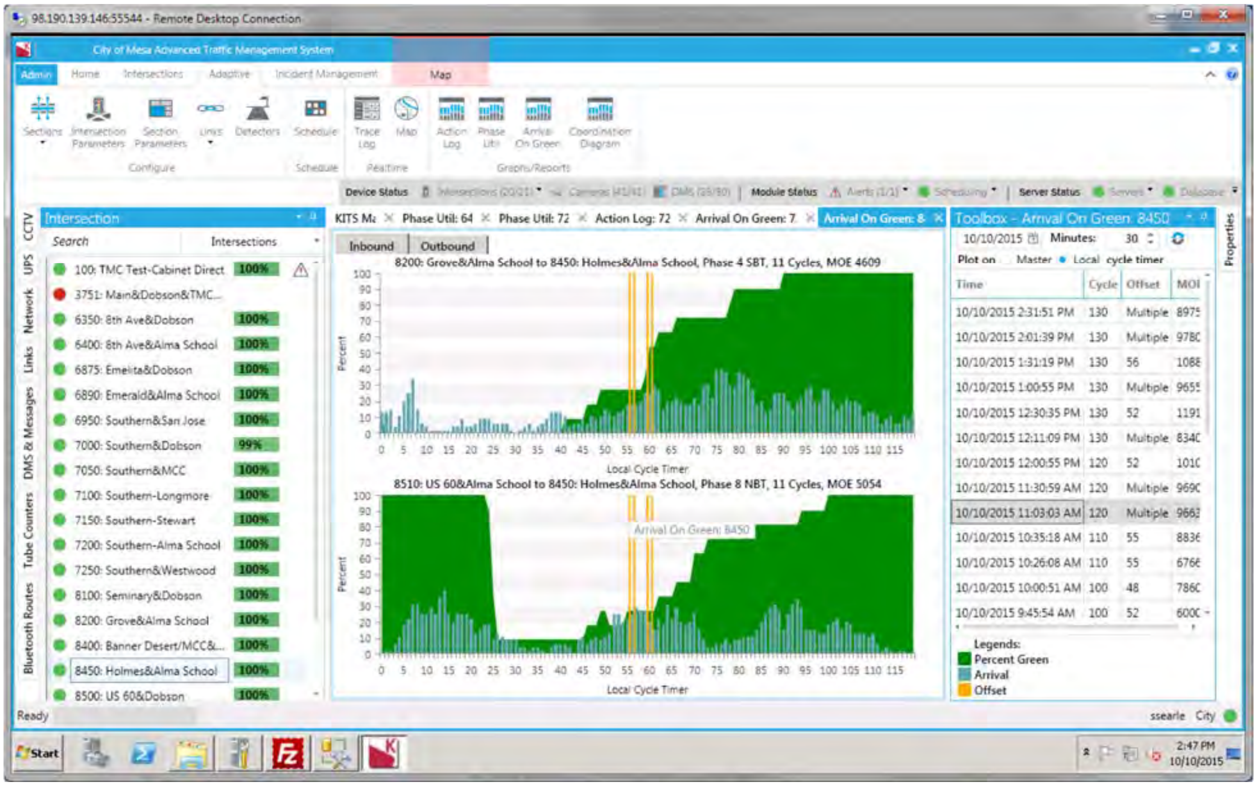


Phase Utilization Output

Strategy #13

Analytics Software and Performance Dashboard for Real-Time Operations Decision Making

Description – Integrate analytics software with the ATMS to collect, analyze, and display traffic data for real-time operations decision making. This will include software and server improvements and identifying staff to be responsible for verifying system outputs. System should be set up to provide reports and alerts to TOC operators when preset thresholds are surpassed or events occur. Data inputs should include, at a minimum, volume, occupancy, speed, and signal timing and sequence. Outputs should include, but not be limited to, performance measures, travel time, queueing, phase utilization, intersection and corridor delay, real-time comparisons to historical data, corridor throughput, and arrivals on green and red.



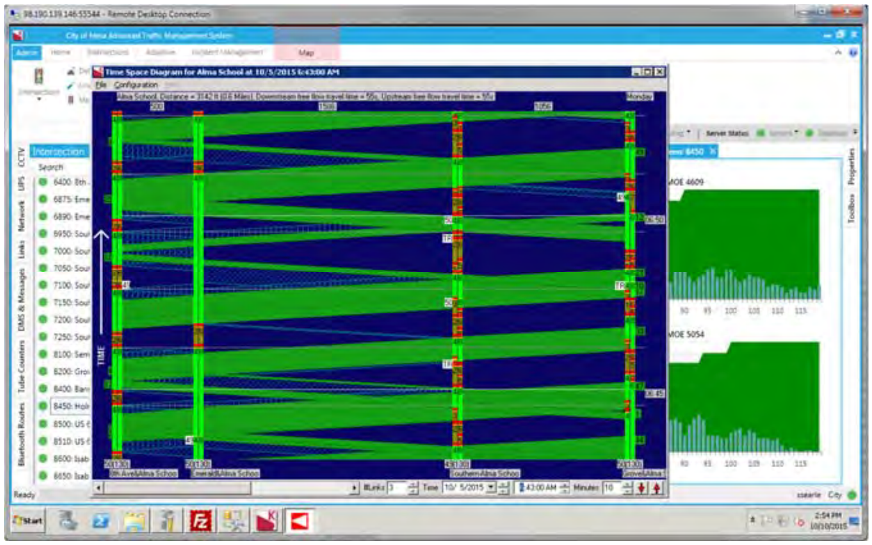
Arrivals on Green Performance Output

Scope/Limits – Procure, implement and integrate software and dashboard. This software will generate automated alerts, provide summary reports on traffic operations, and provide recommendations for improvements to City staff.

Performance Dashboard – A performance dashboard is a management tool that helps capture, track, analyze, and visualize key performance indicators and metrics as they relate to the transportation system. The analytic software should include a performance dashboard for staff to monitor the system in real-time. The performance dashboard should be fully customizable to meet the City's needs, be capable of integration into the City's ATMS, provide data monitoring in real-time, and have an organized, intuitive, and useful display or 'dashboard' for staff to quickly access preset views and reports. It should integrate data from across the transportation division's systems into one location for monitoring and reference. This data should include, performance outputs, system equipment status, crash data and reports, outstanding work orders, transit schedules, public comments and complaints, traffic monitoring video, weather conditions, incident notifications, and construction related lane closure details.

Strategy #14

Implement Citywide Traffic Signal Retiming Program



Time-Space Diagram

Description – Establish a comprehensive citywide signal retiming program to ensure signal timing plans represent current traffic conditions. Develop guidelines and schedules for the evaluation, modeling, and implementation of updated signal plans for all signals. Signal timing plans need to be developed based on current traffic turning movement counts and modeling outputs. Once timing modifications are developed, they will be uploaded to the signal controllers through the ATMS. Ongoing evaluation of corridors is recommended. Fine-tuning of signal timing plans should be completed as it is important to confirm the modeling assumptions and parameters translated correctly to the project corridor.

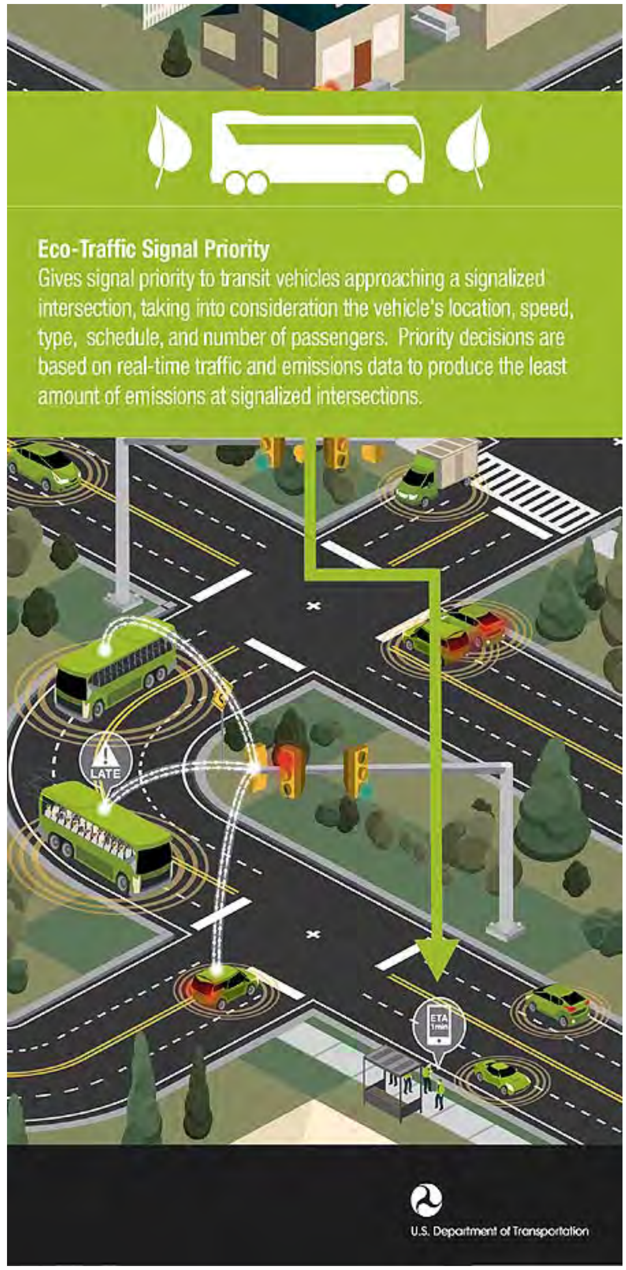
Scope – The City will develop a citywide traffic signal retiming program. Development and continuing execution of the program requires additional staffing, or staff time. However, utilizing newly implemented technology to retime the City's signals will improve the ability to see the impacts and reduce the cost previously associated with signal retiming. This could bring an effort that was traditionally contracted out, in-house, but consultants can also utilize the system. The program should utilize newly collected traffic data, including ATSPMs, to inform retiming priorities as well as timing modifications. Major corridor coordination timing should be evaluated on an annual basis to determine if timing modifications are warranted.

Strategy #15

Implement Transit Signal Priority

Description – Implement transit signal priority (TSP) along key transit routes where congestion has made the reliability of transit service challenging. Deployment of TSP requires a partnership between the City and Regional Transit (RT).

Scope/Limits – Transit signal priority will be deployed on major bus transit corridors to increase reliability, improve travel time, and reduce delays. Deployment of a TSP system requires a partnership between the City of Sacramento and RT. TSP timing, maintenance policies, levels of signal priority, and a concept of operations must be agreed upon by both agencies for the system to be successful. If desired, policy and levels of priority provided could consider the number of passengers on each transit vehicle to most efficiently move people through traffic signals, and not just provide one base level of priority to transit users. The strategy includes installation of TSP equipment at traffic signals and on transit vehicles, modification to signal timing on TSP corridors, and the installation and integration of a TSP ATMS module to provide for monitoring and modifications from the TOC.



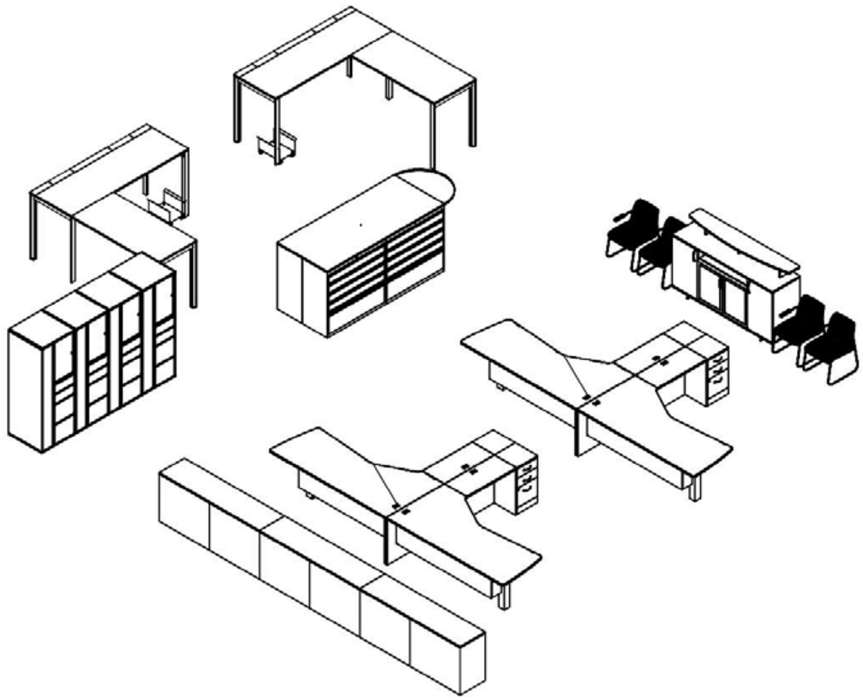
Strategy #16

TOC Upgrade

Description – Upgrade the existing Traffic Operations Center (TOC) including a video wall, extra screens for viewing only, network equipment, workstation layouts, workstation equipment, file storage, bench testing of equipment, network room rack space, cooling and fire suppression systems, and other characteristics of a TOC that require consideration. Additional staff need to be accommodated and access to systems warrants a reallocation of space within the existing TOC. The existing TOC is a good foundation but has some inadequacies for a City of the size and profile of Sacramento. The TOC also lacks enough seating for staff, which is likely to be exacerbated as more signals come online. In addition, there are plans to use the TOC as the City's Emergency Operations Center (EOC) which will require additional functionality and workstations. This strategy includes design, procurement, installation, and integration of new TOC components to upgrade and expand the agency's existing TOC to modern standards and functionality to support the City's increasingly connected transportation system, Emergency Operations Center requirements, and Smart Region initiatives.

Scope/Limits – Design and implement improvements to the existing TOC. The new build-out will have capacity for future staff growth and storage space for future technology requirements. They City will likely need to contract with an appropriate design consultant for planning and design of the TOC upgrades. Some of the critical elements that should be considered for the upgraded TOC include.

- *Workstations*
- *Video Wall and Viewing Distance*
- *Redundant Networking Equipment*
- *Virtualized Servers*
- *Bench Testing Connections and Space*
- *Emergency Operations Center Needs*



Typical TOC Layout (for reference only)

Strategy #17

Establish CAD System and TOC Connections for Automated Alerts and Notifications

Description – Establish filtered Computer Aided Dispatch (CAD) system access at the TOC to see when incidents are restricting lanes and warrant traffic management measures. This strategy will involve communications between the public safety network and the TOC. The CAD system will need to be filtered to anonymous data for lane restriction and location information only, and separate monitors and server will be required at the TOC because CAD will not be integrated into the ATMS system for viewing.

<u>or</u>

Integrate public safety CAD system with the ATMS. This would involve a significant software integration process to update the public safety CAD system to allow it to data push in a specific format to support viewing via the ATMS. Software and servers will need to be installed at TOC to support the connection and integration.

Scope/Limits – Integrate Sacramento County Sheriff CAD system with City's ATMS and TOC. This scope of work includes software integration to update Sacramento County Sheriff CAD system and City's ATMS to allow data push from sheriff CAD system to the ATMS and view the data in the ATMS interface. The scope includes purchase, installation, configuration and integration of servers and software required at City's TOC.

Strategy #18

Establish Agency Network Security Policies and Procedures

Description – Network security training will be a requirement for personnel involved in using, accessing, or securing the City's ATMS, transportation network, traffic signal controllers, and ITS systems. This will involve an update of City networking security procedures and policies. Security training will be provided on a regular basis. This will also include updating procurement specifications to require vendors or firms furnishing new technology to provide training on the functionality and security standards involved with the technology. The City's IT department will be responsible for keeping these policies and procedures up to date with current security requirements of Sacramento's Enterprise System.

Scope/Limits – The Traffic Division will work with City IT staff to establish standard network security policies and procedures for operations and maintenance of the ATMS, the communications network, controllers, and ITS systems, as well as the collection, storage, and dissemination of traffic data.

Strategy #19

Update Existing, and Develop New ITS Standards and Specification Materials

Description – In order to develop a solid foundation for ITS deployment and increase the efficiency of all facets of the transportation system, standardizing the City's traffic signal control and ITS equipment is recommended. Standards to consider include collection of high-resolution traffic condition data and future connected vehicle infrastructure. During the development of ITS standards, it is important to complete a thorough review of current deployments to verify interoperability and identify migration challenges.

Scope/Limits – The City will develop standard details and specifications for design and installation of traffic signal control and ITS equipment.

Strategy #20

Improve Crash Data Collection and Analysis

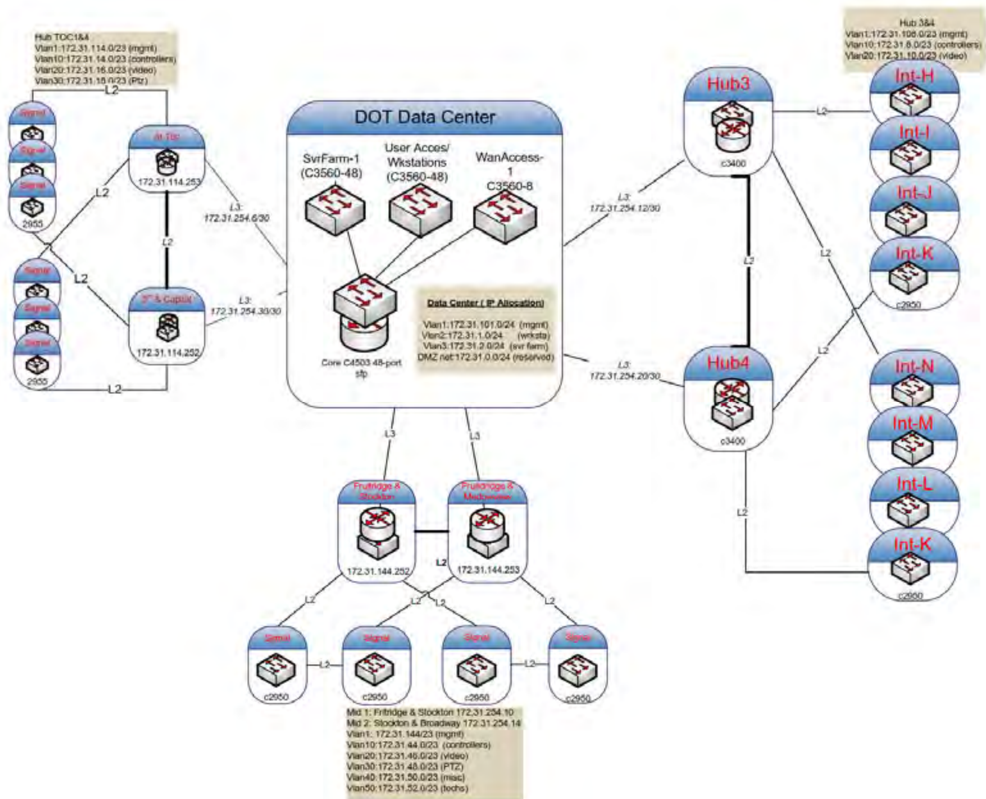
Description – Improve existing procedures for collecting complete, comprehensive, and accurate crash data for the purposes of identifying, evaluating, and planning safety enhancements. Crash data will be collected with planning and analysis use in mind. This may include developing or procuring a crash data application with features that allow for quick geospatial analysis and automated alerts or diagnostic reports. Staff training and improvements to internal procedures may be required as part of this strategy.

Scope/Limits – The City will evaluate the effectiveness of Crossroads crash data application and establish better procedures for the collection of crash data. The Fire Department and Police Department CAD systems should be considered for additional sources of data. A new system may be deemed necessary. The system should be web-based allowing access to data from a variety of applications, most importantly from the Performance Dashboard. Staff will focus on developing analysis procedures, such as collision heat maps, to quickly identify and evaluate problem locations.

Strategy #21

Traffic Signal Communications Network Documentation

Description – Existing documentation of the traffic signal communications network resides in multiple spreadsheets and KML files. The City should collect all available network data and compile it into a useful database and network architecture diagram. All networking and ITS devices should be included and a consistent and expandable IP scheme, including VLANs will be established. This scheme currently exists, but having clear



documentation of the system will provide efficiency during expansion and deployment of new devices as well as aid staff tasked with maintaining the network. As additional fiber-optic routes and ITS devices come online, accurate and detailed records of system architecture and addressing will become even more critical for maintaining a robust and reliable system.

Scope – The City will develop thorough documentation of the traffic signal communications network. The documents should be continually updated as the network expands, and new devices come online.

Strategy #22

Deploy CMS

Description – Deploy Changeable Message Signs (CMS) at key locations within the City. CMS equipment will require devices to be mounted cantilever, on a pole, or over the travel lane. CMS provides the traveling public with on-road information pertinent to their travel. The CMS will need to be integrated into the central management system to allow TOC operators to post relevant messages.

Scope/Limits – Deploy CMS at strategic decision locations to relay traveler information to drivers.

7 ITS Projects

7.1 ITS Project Development

The previous information gathering efforts and the needs assessment guided the development of the City of Sacramento's implementation projects. To support development and expansion of the City's transportation network, several deployment parameters were considered in conjunction with previously discovered information to formulate the overarching implementation criteria. These include:

- ***Emerging Technologies*** – *Projects include provisions for CV technology, multimodal considerations (including transit), and other important initiatives that are advancing innovative technology deployment*
- ***Emergency/Disaster Preparedness*** – *Strategies facilitate the ability to improve the effectiveness of emergency and disaster response.*
- ***Data Availability*** – *The type and quality of available data, how data set can be improved and/or expanded, and how data can be effectively leveraged once it has been analyzed.*

- ***Project Dependencies*** *– Certain project elements must be constructed before other elements can be advanced.*
- ***Overlap with Other Projects*** *– Other projects within the same project area offer efficiencies for construction.*
- ***Safety*** *– Strategy contributes to improved safety.*

Strategies have been developed that will address infrastructure/data, operational, and institutional stakeholder and system needs; and to satisfy this implementation criteria.

7.2 Estimates of Cost

Planning level cost estimates were prepared to reflect an order-of-magnitude cost for each project. A summary of specific costs and considerations related to implementation is provided in **Appendix E – Cost Assumptions**. These assumptions include a detailed breakdown of capital component costs and acknowledges the project development, design, construction, integration, and operations and maintenance costs associated with each project. The cost information is a planning-level estimate to deploy each project, based on available current (2019) pricing information for similar technology projects in the region.

Throughout the development of projects, a distinction was made between projects that carry a cost and those that carry little to no cost. Projects that have costs may require initial capital investments and subsequent ongoing operations and maintenance (O&M) costs. Examples of these projects would be the deployment of new field infrastructure or upgrades to existing traffic operations systems. No cost projects tend to fall more into the institutional category and can be deployed with little to no cost and no future O&M costs. Examples of these projects would be the creation of a set of security guidelines, an interjurisdictional agreement, changes to a policy, or modernizing City standards and specifications.

7.3 ITS Project Elements

The following projects aim to develop a technologically modern, fully-developed transportation system for the City of Sacramento through the implementation of large scale projects. However, it is unlikely that all the improvements will be completed as part of major corridor improvement projects. Because of this, it is beneficial to describe the elements that will be standardized across projects and future deployments allowing the City to develop their system as funding and opportunities arise. The following provides detail on technology recommendations and guidelines for the City of Sacramento when implementing projects to aid planners, engineers, and developers in the build-out of smart technology at traffic signal locations.

The technologies, standards, and practices recommended for future traffic signal projects in the City are summarized below as “ITS Requirements”. To assist the City effectively allocate funding, large or small, an equipment inventory summarizing the status of each of these elements is provided in **Appendix F – Status of Smart Traffic Signal Equipment.**

City of Sacramento - ITS Requirements

Traffic Signal Controller Cabinet

Traffic signal controller cabinets should be at least either NEMA TS-2, Type 1 cabinets, 332L, 332LX, or ATC cabinets, depending on the installation location, intersection characteristics, and controller type. NEMA cabinets should be a minimum Type R to provide for future technology deployments.

Traffic Signal Controller

Traffic signal controllers should be at least either NEMA TS-2 compatible or Model 2070 ATC type controller with Linux based operating system. Controllers should communicate via Ethernet and should meet AB3418, NTCIP 1202, and NTCIP 1207 standards.

Vehicle Detection

Stop bar vehicle detection should be provided by non-intrusive methods, either video or radar technologies. The detectors should be able to detect and discriminate between vehicles and bicycles. The systems must meet bicycle detection requirement *Assembly Bill AB-1581* and the *CAMUTCD*. Advance vehicle detection is required on approaches with speeds over 25 mph or as required by the City. The City should continue to test video and radar technologies for advance detection. When a reliable and accurate advance detection system, capable of providing vehicle ETA at a minimum, is found to be acceptable to staff, the City should standardize on it in place of its current standard inductive in-pavement loops.

Traffic Monitoring Camera

Traffic monitoring cameras, or closed-circuit television (CCTV) cameras should be pan-tilt-zoom (PTZ) type, high definition (HD), and Internet Protocol (IP) compatible. Traffic monitoring cameras should be deployed at all traffic signals unless otherwise directed.

Ethernet Switch

Ethernet switches are required at traffic signals and should be Layer 2 with a minimum of two (2) Gbps small form-factor pluggable (SFP) ports capable of accepting optical transceivers for communications over fiber-optic cable. In addition, switches should have a minimum of eight (8) 100 Mbps RJ45 Ethernet ports for other signal appurtenances.

Emergency Vehicle Preemption

New emergency vehicle preemption systems are required and should be GPS and/or radio based and should be compatible with the City's and the City of Sacramento Fire Department's existing system. The system's phase selector or discriminator should be IP addressable for remote monitoring and programming.

Battery Back-up System

Battery back-up systems should include a NEMA 3R enclosure capable of housing all components. The system should include at a minimum a ruggedized Uninterruptible Power Supply (UPS), a bypass switch, and batteries rated for outdoor use and the traffic signal's design load. The UPS should be IP-addressable for remote monitoring. BBS should be installed at all traffic signals unless otherwise directed.

7.4 ITS Projects List

A summary of projects with associated costs are presented in Table 1 – ITS Project Summary**Table 1.**

Table 1 – ITS Project Summary

Project #	Project Name and ID	Project Description	Planning Level Cost Estimate
1	**Downtown Grid Major Corridors** *(Project G1)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 1 mile of communications conduit, 7.5 miles of fiber-optic cable, and 136 traffic signal upgrades)*	$9,600,000
2	**Natomas Blvd. ITS Project** *(Project B)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 4 miles of fiber-optic cable, and 18 traffic signal upgrades)*	$1,700,000
3	**Del Paso Blvd. ITS Project** *(Project H)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 3.5 miles of communications conduit, 4.5 miles of fiber-optic cable, and 29 traffic signal and upgrades)*	$4,600,000
4	**J St. ITS Project** *(Project J)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 2 miles of communications conduit, 5 miles of fiber-optic cable, and 36 traffic signal upgrades)*	$5,000,000

Project #	Project Name and ID	Project Description	Planning Level Cost Estimate
5	**Riverside Blvd. ITS Project** *(Project R)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 7.5 miles of communications conduit, 11 miles of fiber-optic cable, and 24 traffic signal upgrades)*	$8,900,000
6	**Bruceville Rd. ITS Project** *(Project L)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 2.5 miles of communications conduit, 7 miles of fiber-optic cable, and 23 traffic signal upgrades)*	$4,700,000
7	**El Camino Ave. ITS Project** *(Project F)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 6 miles of communications conduit, 8 miles of fiber-optic cable, and 35 traffic signal upgrades)*	$6,500,000
8	**Downtown Grid Capitol Mall and Southside Park** *(Project G2)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 1 mile of communications conduit, 1.5 miles of fiber-optic cable, and 53 traffic signal upgrades)*	$3,700,000
9	**Folsom Rd. ITS Project** *(Project K)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 0.5 miles of communications conduit, 2 miles of fiber-optic cable, and the 24 traffic signal upgrades)*	$2,000,000

Project #	Project Name and ID	Project Description	Planning Level Cost Estimate
10	**Franklin Blvd. ITS Project** *(Project P)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 5 miles of communications conduit, 7 miles of fiber-optic cable, and the 46 traffic signal upgrades)*	$7,000,000
11	**Del Paso Road ITS Project** *(Project C)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 0.5 miles of communications conduit, 2 miles of fiber-optic cable, and 13 traffic signal upgrades)*	$1,700,000
12	**Downtown Grid: Midtown Secondary Arterials** *(Project G3)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 0.5 miles of communications conduit, 4.5 miles of fiber-optic cable, and 73 traffic signal upgrades)*	$4,800,000
13	**Fruitridge Road ITS Project** *(Project O)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 2 miles of communications conduit, 4 miles of fiber-optic cable, and 26 traffic signal upgrades)*	$3,800,000
14	**Arden Way ITS Project** *(Project I)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 1.5 miles of communications conduit, 3 miles of fiber-optic cable, and 25 traffic signal upgrades)*	$2,800,000

Project #	Project Name and ID	Project Description	Planning Level Cost Estimate
15	**Elkhorn Blvd. ITS Infrastructure Project** *(Project A)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 4 miles of new communications conduit, 6.5 miles of fiber-optic cable, and 14 traffic signal upgrades)*	$5,300,000
16	**San Juan Rd. ITS Project** *(Project E)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 3.5 miles of communications conduit, 6 miles of fiber-optic cable, and 14 traffic signal upgrades)*	$4,400,000
17	**Meadowview Rd./ Franklin Rd. ITS Project** *(Project S)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 2 miles of communications conduit, 1 miles of fiber-optic cable, and 40 traffic signal upgrades)*	$3,200,000
18	**Arena Blvd. ITS Project** *(Project D)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately* 2 miles of communications conduit, 3 miles of fiber-optic cable, and 19 *traffic signal upgrades)*	$2,900,000
19	**Florin Perkins Rd. ITS Project** *(Project M)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of	$4,200,000

Project #	Project Name and ID	Project Description	Planning Level Cost Estimate
		updated signal timing and coordination. *(approximately 1.5 miles of communications conduit, 6 miles of fiber-optic cable, and 30 traffic signal upgrades)*	
20	**24th St. ITS Project** *(Project Q)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 0.5 miles of communications conduit, 3.5 miles of fiber-optic cable, and 11 traffic signal upgrades)*	$2,000,000
21	**Norwood Ave. ITS Project** *(Project G)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 1 mile of communications conduit, 1.5 miles of fiber-optic cable, and 18 traffic signal upgrades)*	$3,100,000
22	**Stockton Blvd. ITS Project** *(Project N)*	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 0.5 miles of communications conduit, 0.5 miles of fiber-optic cable, and 25 traffic signal upgrades)*	$2,400,000
23	**Downtown Grid Railyards Blvd.** (Project G4)	Project includes enhanced communication infrastructure through installation of new fiber-optic cable and replacement of existing copper signal interconnect; installation of new cabinets and controllers, deployment of modern video detection; installation of CCTV cameras; study and implementation of updated signal timing and coordination. *(approximately 1 mile of communications conduit, 5 miles of fiber-optic cable, and 18 traffic signal and upgrades)*	$800,000
24	**Asset Management Project**	Upgrade asset management system and maintenance work order system	$150,000

Project #	Project Name and ID	Project Description	Planning Level Cost Estimate
25	**ATMS Upgrades**	Procurement of upgrades and add-ons for ATMS to incorporate new functionality. Integrate back end software linked to ATMS to analyze data for real-time operations	$250,000
26	**Spare Equipment Project**	Procure spare ITS equipment	$1,200,000
27	**Staffing**	Increase Staffing Levels to Improve Real-Time Operations	Salary-dependent
28	**CAD System and TOC Connections**	Establish CAD System and TOC Connections for Automated Alerts/Notifications	$900,000
29	**Infrastructure Replacement Program**	Develop an Infrastructure Replacement Plan for end-of-life equipment	N/A
30	**Preventative Maintenance Program**	Develop a Preventative Maintenance Plan for traffic signal equipment and communications equipment	N/A
31	**Traffic Signal Retiming Program**	Develop an internal Traffic Signal Retiming Program to direct when and where to perform retiming of City corridors.	N/A
32	**Technology Education and Piloting Program**	Develop a Technology Education and Piloting Program to educate staff on new City technologies and provide direction on testing innovative technologies	N/A

8 Operations and Maintenance

To effectively operate and maintain the various project elements and projects identified in this plan, the City of Sacramento must be adequately staffed and prepared to sustain the system after deployment. Operations and maintenance procedures are essential to define the appropriate staffing levels, training, operational processes, and maintenance levels necessary to sustain an effective system.

8.1 Staffing

The successful implementation of operations and maintenance strategies is largely dependent on providing appropriate staffing to perform these strategies.

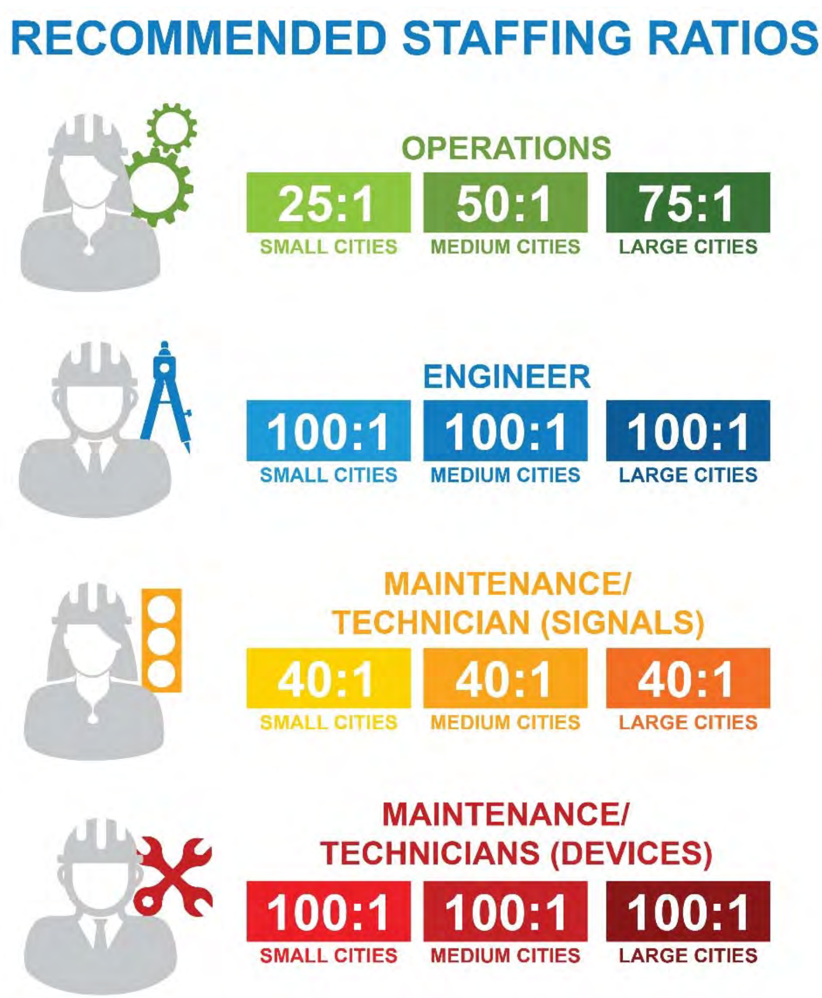
Inventory of transportation assets in the City has steadily increased without a corresponding increase in staff to operate and maintain them. This has created a situation where the City is understaffed for operations as well as for maintenance of the traffic signal and ITS network infrastructure.

Staffing for ITS

The City of Sacramento should follow a staffing plan that addresses five key objectives:

1. Ensure appropriate staffing levels based on increasing and aging assets;
2. Employs staff with the requisite knowledge, skills, and ability in appropriate positions;
3. Ensure the organization adapts to changes internally and externally;
4. Provide a systematic approach for human resource management; and
5. Provide a shared vision of human resource functions.

The following provides recommended ratios for the number of devices or signals to warrant one staff person for small, medium, and large jurisdictions based on the total number of devices or signals the jurisdiction is expected to operate and maintain. Operations staff are responsible for daily monitoring and use of transportation management assets. Engineers are responsible for conducting analysis of system performance and developing solutions. Maintenance staff are responsible for preventative and routine servicing of field assets.



Staffing Considerations

Deploying additional ITS infrastructure and functionalities desired by the City and recommended in this Plan will exacerbate the City's staffing shortage. To combat this, a process must be put in place to identify and account for staffing needs for the City's ITS infrastructure. A process should be put in place, as part of the capital project programming process for traffic signals and other ITS communications projects, that requires consideration of staffing resources needed to operate and maintain the new infrastructure in addition to existing infrastructure.

When pursuing additional or adjusted staffing to account for ITS improvements, the City should consider the following:

> ***Heightened Skill Set*** – Central management systems are undergoing fundamental changes, including the introduction of more sophisticated technologies, a shift to integrated operations (multiagency, multimodal), and improvements to customer service capabilities. The increased demand for services

and changes to central management system operations influence the required staffing skillsets. In many cases, personnel required to manage intelligent transportation systems have an Information Technology (IT) background and skillsets that includes network management, software development, database administration, or application troubleshooting. Although engineering experience or a professional license may be warranted for specific activities, such as signal timing development, an engineer may not always be necessary to fulfill City functions. Sacramento should consider a combination of personnel skillsets to fulfill its operations and maintenance needs.

Redundant Support Structure – It is important to foster and maintain staff skills and redundancy through greater training and cross-training so more than one person possesses the knowledge and skillset required to operate and maintain the City's ITS equipment and systems.

Central System Management Architecture – Another factor that has a significant impact on staff planning is whether the central management system operations will function only out of the City's Traffic Operations Center (TOC) through the workstations and video wall, or if the central management system will also be operated on a virtual basis in other City offices and facilities. This will determine if the TOC will need permanent operations staff, or if staff will be able to support traffic operations when not on-site.

TOC positions are based on old classifications that do not cover all of a modern TOC's job duties. Job classifications should be reviewed and modified to match the needs of the City's transportation system. Review of other similar sized agencies should be conducted. Positions such as ITS engineer, traffic operations engineer, or traffic operations specialist should be considered.

8.2 Maintenance Plan

A maintenance plan prescribes preventative maintenance and defines the criteria for replacement of infrastructure. The number of devices and systems to be maintained in the City is expected to increase in the near-term based on the programmed ITS infrastructure projects. These devices and systems need to be appropriately maintained to provide accurate, reliable, and timely information.

Maintenance activities fall into two categories: preventive and responsive. Preventive maintenance involves the periodic calibrating, cleaning, or fine-tuning of equipment to prolong the acceptable performance of the equipment. Responsive maintenance involves the troubleshooting, repair, or replacement of failed equipment, usually prioritized based on severity of the failure.

Preventative Maintenance

Preventative maintenance is performed to ensure the reliability and longevity of the mechanical and electrical operations of the system and will reduce equipment failures, responsive maintenance, road user costs, and liability exposure. The City should develop a maintenance checklist for maintenance crews to use and develop a schedule for when the periodic check-ups should take place. Preventative maintenance activities and frequency varies by device, device components, and system. The following graphic provides a typical checklist and intervals. The City should review and revise the preventative maintenance procedures on an annual basis to ensure new issues are being addressed and equipment is being properly maintained.

Preventative Maintenance Checklist

Interior Cabinet Check	Annually	Monthly	Weekly
Clean Cabinet Interior	✓		
Check controller lamp and door switch	✓		
Check filter	✓		
Check door fit and gasket	✓		
Check locks and hinges	✓		
Check/verify for cabinet timing and log sheet	✓		
Check field block terminal connections	✓		
Signal controller battery backup check	✓		
Certify conflict monitor	✓		
Check all detectors	✓		

Exterior Cabinet Field Check	Annually	Monthly	Weekly
Check condition of cabinet exterior	✓		
Check all signal indications	✓		
Check all pedestrian indications	✓		
Check pole conditions and hand hole covers	✓		
Check all signal head back plates and visors	✓		
Check alignment of signals and pedestrian heads	✓		
Check condition of pull boxes and lids	✓		

Intersection Field Check	Annually	Monthly	Weekly
Visual check of all traffic signs at intersection	✓		
Visual check of intersection luminaires	✓		
Visual check of all traffic loops	✓		
Visual check of other traffic system related cabinets	✓		

Responsive Maintenance

To address responsive maintenance, the City must develop contingency plans to address inevitable unforeseen device failures. Devices may inadvertently be damaged or may unexpectedly fail due to unforeseen device malfunctions. To address these issues, the City should budget for an inventory of spare equipment for future replacement of failed equipment. The City should maintain two to three percent of the total deployment for adequate spare devices to have on hand for maintenance purposes, plus an open purchase order for seven to eight percent (totaling 10 percent total).

Maintenance Tracking

The City should deploy a maintenance tracking system to keep a database of maintenance activities that have occurred on each device and system. The tracking database should include, at a minimum, the following maintenance activities:

- *Failure detection;*
- *Work order creation;*
- *Dispatched resources;*
- *Response activities;*
- *Diagnosis;*
- *Interim repairs; and*
- *Work order close out.*

Maintenance tracking will allow the City to identify devices that are unreliable, inaccurate, or frequently malfunction. This tracking will also allow the City to identify appropriate cases for technology replacements where maintenance of an existing technology may be costlier than upgrading to a newer technology. Developing and reviewing periodic reports is critical to identifying frequently failing devices for replacement.

9 Performance Metrics

Performance metrics are used to evaluate and demonstrate the effectiveness of the City of Sacramento's ITS projects in addressing local and regional objectives. Recommended data types, data sources, and calculations to evaluate performance of projects are provided in **Table 2**. As projects are delivered, the City of Sacramento can use these metrics as a guideline to evaluate projects.

Table 2 – Performance Metrics to Perform Project Evaluations

Objective	Performance Metric	Data Type	Source	Calculation
	Reduced Travel Time	Travel Time	Sacramento TOC	Travel time in minutes between Point A and Point B prior to and after project implementation
	Increased Transit Ridership	Sales/Revenue	Transit Provider Records	Count ridership levels before and after project

Objective	Performance Metric	Data Type	Source	Calculation
Address **smart** transportation **strategies** for urban, suburban, and rural communities				implementation, calculate percentage change
	Incident detection by CCTV cameras	CCTV Images	Sacramento TOC	Count incidents that are detected via CCTV camera before being identified by public
	Accurate Travel Time Estimates (particularly focused on rural and suburban communities with commuting needs)	Travel Times	Sacramento TOC	Compare travel times estimated and actual travel times to verify accuracy for those commuting into urban centers from rural or suburban communities
Prepare for **smart** region **infrastructure** adapting to new technology	Number of hours (in 6-month intervals) of continued education or training completed by staff	Training Hours	CE courses, Vendor Training Seminars, etc.	Count hours staff spent attending new technology trainings or pursuing certifications
	System Readiness for Connected Vehicle Technology Integration	CV Technology (Device and Data)	Sacramento TOC	When applicable, monitor CV technology integration and compare qualitatively or quantitively with other region's technology integration experiences
	Increase Capacity of Communications Network	Fiber/Wireless/ Bandwidth Usage	Sacramento TOC	Measure communications network capacity before and after ITS device deployment
Reduce user frustration by providing **consistency and reliability**	Reduced Downtime	System Errors/ Failure	System Operations	Compare Downtime Incident Occurrences before and after project implementation
	Reduced Public Complaints	Public Complaints	TOC and other Operator Records	Compare the amount of public complaints related to inconsistency/unreliability from before and after implementation project
	Reduce Response Time to Device Failures	Response Time	TOC and Dispatch Records	Measure reduction in response times before and after project implementation
	Increase percent of field device that are operational	Operational Devices	Asset Management System	Calculate percent of devices that are operational based on total devices in the inventory. Compare that figure to the same percentage ratio prior to implementation project

Objective	Performance Metric	Data Type	Source	Calculation
Proactively improve transportation system **safety**	Reduced vehicle-to-vehicle crashes	Crash Records	Crash Record System	Calculate percentage change of crashes before and after implementation
	Reduced vehicle-to-bicycle crashes	Crash Records	Crash Record System	Calculate percentage change of crashes before and after implementation
	Reduced vehicle-to-pedestrian crashes	Crash Records	Crash Record System	Calculate percentage change of crashes before and after implementation
	Reduced Safety Incidents Involving Transit Operations	Transit Incident Records	Transit Provider Records	Count amount of safety incidents involving transit operations after project implementation and compare to before implementation
Improve **traveler information** and dissemination to public and within region	Reduced vehicle traffic (congestion) due to CMS Message	Traffic Volume	Sacramento TOC	Difference between Pre/Post CMS Traffic Volumes on Corridor and Alternate Corridor
	Increased Social Media Presence via Agency Managed Apps/Websites	Social Media Posts and Push Notifications (Facebook, twitter)	PR/PIO Records	Track social media outputs, compare to posts prior to implementation strategies
	Increased Partnerships between Third Party Data Companies and Public Agencies	Partnerships	Institutional Policies/Documents	Count the number of private party/public agency data sharing agreements that have occurred since implementing strategies
	Increased 511 Inputs (on all available platforms)	Website Updates, Radio Updates, and Push Notifications	511 System/ Records	Count traveler information inputs that are sent out through 511 systems and compare it to counts prior to implementation
	Increased 511 Usage/Subscriptions	App Download/Website Usage	App/Website Management	Count of 511 website views
Disaster preparedness	Improved Emergency Response Time	Travel Time	Sacramento TOC	Time between initial notification to first responder arrival
	Improved Incident Clearing Times	Incident Response and Clearing Times	Sacramento TOC	Compare time it takes to respond to and clear an incident before and after strategy implementation

10 Next Steps

This document, as adopted by City Council, provides focused direction to City staff to implement the strategies, priorities, and investments outlined in the Plan. The outcome of this ITS Master Plan is a roadmap of strategies and projects that the City of Sacramento can follow to systematically implement technology projects that achieve local and regional objectives through expansion of infrastructure, integration of systems and subsystems, and deployment and readiness for emerging technologies.

This Plan assists City staff with the following:

- *Provides a guide to decision making when programming local dollars at the beginning of each fiscal year, either for direct local expenditure, or set aside for grant match.*
- *Assists in determining which projects, both specific and those strategies more programmatic in nature, can be submitted for federal and state grant opportunities.*

- *Serves as a tool to identify standard CIP improvements, with a focus at the onset of the projects' development, serving as a policy document which helps avoid project development surprises.*
- *Helps to communicate to SACOG and other state/federal grantors that the City has an ITS policy on which the elected leaders have agreed and invested.*
- *Establishes a framework for project prioritization.*
- *Assists with internal workload prioritization.*

This plan and the associated tools should remain a living set of resources that staff can update as projects are implemented or expanded, agency priorities change, or other changes occur that impact the region or the City of Sacramento. In addition, it is particularly important to maintain a process to update the Plan because of the deployment phasing methodology used.

10.1 Plan Components to Update

Deployment Phasing – It will be particularly important to update the Plan to reflect projects that have been completed. Priorities across projects may also change and should be reflected in the document. As time goes by and projects shift from phase to phase, updating will provide an opportunity to evaluate if new projects are available based on emerging technology, increased staffing levels, and so on.

Funding Opportunities – Funding opportunities are always changing. Existing programs or grants may expire, while new ones may emerge. It is imperative that funding opportunities are kept current to maximize the opportunity to utilize new funding sources. In addition, it will continue to be important to leverage emerging opportunities for third party or private sector support.

Equipment Replacement Strategies – The success of this Plan is largely based on ensuring that all equipment continues to work effectively and efficiently. Legacy equipment should be continuously updated or replaced to accommodate emerging technology and enhanced system functionality.

Operations and Maintenance – Adequate staffing levels allow for optimal functionality. As the plan grows and progresses, staffing levels must continue to reflect the need for sustaining a functioning system.