Appendix 3.5.1
ITS Memo

TECHNICAL MEMORANDUM

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Date:	May 20, 2016		
RE:	Alameda County Multimodal Arterial Plan – Traffic Management Coordination Strategies, Policies & Best Practices Technical Memorandum		

1 | Introduction

Project Overview

Alameda CTC is developing a Countywide Multimodal Arterial Plan that will provide a framework for identifying, prioritizing, and implementing proposed improvements that will address needs of all modes on the County's arterial roadways. As a basis to identifying these improvements, the Multimodal Arterial Plan evaluates the existing performance of Alameda County's arterial roadways to gain a better understanding of how these roadways currently serve multimodal users throughout the County. Based on this understanding, the Multimodal Arterial Plan can assess multimodal needs of users across the county, which will ultimately feed into identifying the appropriate improvements to address multimodal needs on the arterial roadways countywide.

Technical Memorandum Overview

The purpose of this memo is to review and document the existing ITS conditions and to outline ITS strategies, policies, and best practices to achieve Alameda CTC's goals for improved mobility, travel reliability, and modal connectivity on the arterial network as well as agency needs. The focus of this document are the automobile and transit modes only. With respect to other modes, some auto and transit focused ITS strategies may also benefit bicyclists and pedestrians. ITS strategies such as bicycle detectors and pedestrian count-down signals are aimed at those modes however they are not included in this document's recommendations. This document will present ITS improvement recommendations for the 510-mile Arterial Network which represent arterials of Countywide significance and serve as the backbone of multimodal mobility throughout the county. ITS recommendations will only focus on arterial network segments that were identified in the Arterial Plan's needs assessment as having an improvement need for automobiles and/or transit priority corridors. Finally, Next Generation vehicle technologies and their impact on the ITS infrastructure will be addressed at a high level in addition to the other recommended strategies and technologies. This document will discuss potential changes in technology and infrastructure that would need to be considered for implementation within the public right-of-way to accommodate and support Next Generation vehicles.

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2 | Existing Conditions Summary

In November 2014, the project team and Alameda CTC finalized the vision and goals that will serve as a guide for prioritizing investments and designing projects and programs, including ITS, to address important transportation issues in the county and region. The coordinated technology measure assesses the level of ITS infrastructure along the Study Network. The measure is based on a zero to three point scale based on the level of ITS investment defined by the built infrastructure. Existing levels of ITS infrastructure are identified based on the following general categories:

- **Level 0** - No ITS infrastructure in place. Generally, traffic signals along a corridor are not interconnected and there's no communications back to a central location (e.g., transportation management center, or TMC) to remotely monitor or manage traffic signals.
- **Level 1 -** Low level of ITS infrastructure that generally corresponds to the ability to remotely monitor and manage field devices from a central location (e.g., TMC). Traffic signals along a corridor are interconnected and allow communication back to a TMC where there is a central system to actively manage field devices.
- **Level 2 -** Medium level of ITS infrastructure that corresponds to everything described above plus the additional ability to visually monitor and/or react to traffic conditions in real time from a central location. This includes having devices such as closed-circuit television (CCTV) cameras, adaptive signal timing controls, and/or transit signal priority controls.
- **Level 3** - High level of ITS infrastructure that corresponds to everything described above plus the additional ability to actively inform and influence traffic flow in real-time from a central location. This includes devices such as changeable message signs or any connected vehicle (vehicle to infrastructure) capabilities.

Existing conditions data was collected for 1,200 miles of major arterials called "Study Network" for the MAP. The Arterial Network of 510 miles mentioned above is a core and subset of this Study Network. Coordinated technology was summarized for about 75 percent, or 386 miles, of the Arterial Network as ITS infrastructure data was not readily available for the remaining 25 percent. Of the Arterial Network segments with data coverage, the majority of segments provide low or no ITS infrastructure. The inventory of ITS infrastructure levels is based on data provided by jurisdictions in addition to a review of the projects included in the 2011 Bay Area ITS Architecture, soon to be completed 2016 Bay Area ITS Architecture as well as the consultant team's knowledge of the countywide ITS infrastructure network.

Of the Arterial Network segments with available data:

- 10% of segments provide High level of ITS infrastructure,
- 29% of segments provide Medium level of ITS infrastructure,
- 46% of segments provide Low level of ITS infrastructure, and
- 15% of segments do not provide any ITS infrastructure.

Major ITS Programs and Infrastructure

The following summarizes major ITS program investments currently or soon to be in operation within Alameda County.

- **I-80 Integrated Corridor Management (ICM) Program:** This project is slated to be operational in Summer 2016. Within Alameda County, this project covers the cities of Albany, Berkeley, Emeryville, and Oakland. The arterial and transit portions of the program is along San Pablo

Avenue and the major arterials that connect I-80 and San Pablo Avenue with a focus on improving operation through the use of ITS enhancements. ITS elements implemented along arterials within the program include CCTV cameras for roadway monitoring, signal controller upgrades and communications to traffic signals for traffic responsive signal operations, trailblazer signs for incident management, and transit signal priority for enhanced transit performance.

- **San Pablo Avenue Smart Corridor:** Part of the East Bay Smart Corridors program. This program has been in place since the early 2000's and focused on the implementation of ITS elements along the San Pablo Avenue corridor within Alameda County limits. ITS elements deployed as part of the program included CCTV cameras for roadway monitoring, equipment for emergency vehicle preemption (EVP) and transit signal priority (TSP) operations, and signal coordination. Communications was primarily provided through leased-lines from telecom companies. To a large extent, the ITS enhancements provided under this program are being folded into the I-80 ICM project.
- **International Boulevard/Telegraph Avenue/East 14th Street (INTEL) Smart Corridor:** Part of the East Bay Smart Corridors program and similar to the San Pablo Avenue Smart Corridor, this program has also been in place since the early 2000's. ITS elements deployed as part of the program included CCTV cameras for roadway monitoring, equipment for emergency vehicle preemption (EVP) and transit signal priority (TSP) operations, and signal coordination. Communications was primarily provided through leased-lines from telecom companies.
- **I-880 ICM Program**: This program runs the length of Interstate 880 in Alameda County and seeks to manage traffic that naturally diverts from the freeway due to major incidents on I-880. The arterial incident management portion of the project proposes to initially install ITS equipment on arterial streets along the I-880 Corridor in the cities of Oakland and San Leandro. As of this writing the initial segment will be implemented by 2017. In the long term, the corridor is slated to expand to extend into Santa Clara County and include the length of the interstate. Project components include trailblazer signs, cameras, detection stations, signal coordination and communications improvements.
- **Interstate 580/680 Tri-Valley Smart Corridor Program:** This program has been in place since the early 2000's and focused on the implementation of ITS elements within the Tri-Valley cities of Dublin, Pleasanton, and Livermore. ITS elements deployed as part of the program included new central signal systems in each city, fiber optic communications, and CCTV cameras for roadway monitoring. A key element of the ITS enhancement included center-to-center communications where the fiber optic network interconnects each city's Traffic Management Center allowing for the sharing of video and data between each city.
- **I-580 ICM Program**: Currently in the initial planning stages, this program covers I-580 from I-238 in Castro Valley to the Alameda County-San Joaquin County line. Similar to the I-880 ICM, this program seeks to manage traffic that naturally diverts from the freeway due to major incidents on I-580 in the cities of Pleasanton, Dublin, Livermore and unincorporated Alameda County.
- **Webster Street Smart Corridor**: The project is located along the Webster Street corridor at six intersections between Central Avenue and the Alameda ingress and egress of the Webster/Posey tubes (State Route 260); as well as Constitution Way in the City of Alameda. It also includes signal timing work at the intersection of Harrison and 7th Streets in Oakland. The project will implement an Intelligent Transportation System (ITS) to improve safety and operations of transit and vehicular modes; enhancing mobility and safety in this vital corridor which connects the City of Alameda to I-880 and the City of Oakland. The project includes implementation of an Emergency Vehicle Preemption (EVP) system to improve emergency response time for fire departments, implementation of a Transit Signal Priority

(TSP) system to promote transit use and implementation of an Advanced Traveler Information System (ATIS) to inform public of street, freeway and tunnel conditions in real-time.

- **East Bay Bus Rapid Transit:** The limits of this project spans between downtown Oakland and the San Leandro BART station, within the cities of Oakland and San Leandro and expected to be operational in 2017. ITS elements deployed as part of this project primarily consist of transit signal priority along the project corridor consisting of: Broadway, 11th/12th Streets, E. 12th Street, International Boulevard, East 14th Street, Davis Street, and San Leandro Boulevard.
- **Next Generation Arterial Operations Program**: MTC's NextGen AOP was initiated in 2014 as a pilot program to assist local agencies in implementing advanced technologies to better manage and operate their arterials. The NextGen AOP explores and implements the benefits of advanced technologies that can improve travel time and travel time reliability for autos and transit vehicles along arterials, as well as improve the safety of motorists, transit riders, pedestrians, and bicyclists. These technologies may include adaptive signal control systems, transit signal priority, real-time traffic monitoring, and other innovative operational strategies. Three of the four selected pilot deployments are located in Alameda and include:

    - **City of Fremont:** Implementation of an adaptive signal control system and real-time traffic monitoring for 9 intersections along a 2.2 mile section of Fremont Boulevard.
    - **AC Transit Line 97:** Implementation of an adaptive signal control system for 34 intersections along the Hesperian Blvd. portion of the corridor between the cities of San Leandro and Hayward and implementation of transit signal priority for 61 intersections along the entire project corridor between the cities of San Leandro and Union City.
    - **LAVTA/City of Dublin:** Implementation of an adaptive signal control system for 16 intersections along the 2.9 miles stretch of Dublin Blvd. The new adaptive signal control will work with the existing transit signal priority system to improve corridor operations and performance.

Local ITS Infrastructure

In general, agencies within Alameda County with the highest level of ITS infrastructure are located in the central, east, and south portions of the county. **Table 1** provides a high level summary of the ITS infrastructure utilized by local agencies in the County. These agencies generally have a dedicated communications infrastructure to support ITS-related operations such as a centralized monitoring and control of the local roadways. This baseline of ITS infrastructure, especially a communications network, enables for easier expansion of other ITS-related improvements since the supporting infrastructure needed is already in place. These agencies have a history of strong local support and funding of ITS related improvements.

Agencies in the north portion of the county tend to have a lower level of ITS infrastructure. What ITS infrastructure that does exist is generally isolated to ITS elements installed as part of larger regional initiatives such as the San Pablo Smart Corridor or I-80 ICM programs. As such, ITS infrastructure in these agencies are typically limited to the roadway corridors encompassed by these regional programs. For example, in the cities of Albany, Berkeley, and Emeryville, the existing ITS infrastructure is focused on San Pablo Avenue and the east-west roadways (Buchanan St., Gilman St., University Ave., Ashby Ave. and Powell St.) connecting I-80 and San Pablo Avenue that are part of the I-80 ICM.

Table 1 - Existing ITS Infrastructure

JURISDICTION	Central Signal System (Tier – 1)	High Bandwidth Communications (Tier 2)	Visual Monitoring (Tier – 2)	Route Guidance (Tier – 3)	Transit Priority (Tier – 2)	Adaptive Signal Operations (Tier – 2)
Alameda						
Albany			X	X	X	
Berkeley			X	X	X	
Emeryville			X	X	X	
Oakland		X		X	X	
Piedmont						
San Leandro	X	X	X		X (2)	X (1)
Hayward	X	X	X		X (2)	X
Dublin	X	X	X		X	X (1)
Pleasanton	X	X	X			
Livermore	X	X	X			
Union City	X				X (2)	
Fremont	X	X	X			X (1)
Newark						
Alameda County					X (2)	X (1)
Caltrans			X	X	X	

(1) Adaptive signal operations will be implemented in San Leandro, Alameda County, Dublin, and Fremont as part of MTC's Next Generation Arterial Operations Program.
(2) Transit signal priority will be implemented in San Leandro, Hayward, Union City, and Alameda County as part as part of AC Transit's Line 97 project funded through MTC's Transit Performance Initiative and Next Generation Arterial Operations Program.

3 | Arterial Network Needs

The vision, goals and supportive principles discussed in Section 1 of this document were used to create performance objectives/needs which will be used to develop strategies for satisfying those needs. The focus of this section is to identify the needs of different modes estimated through the Needs Assessment step that can be at least partially satisfied through the deployment of Intelligent Transportation System (ITS) strategies.

The *Alameda Countywide Multimodal Arterial Plan – Final Needs Assessment* technical memorandum prepared by Fehr & Peers dated February 22, 2016 presented performance measures/objectives and needs for several modes of transportation transit, pedestrian, bicycle, automobile and goods movement. Given that the focus of this document is automobile and transit modes only, Iteris identified which needs for those two modes could be at least partially satisfied by ITS strategies. With respect to other modes, some auto and transit focused ITS strategies may also benefit freight, bicyclists and pedestrians. ITS strategies such as bicycle detectors and pedestrian count-down signals are aimed at those modes specifically however they are not included in this document's recommendations.

Similarly, strategies aimed specifically at Commercial Vehicle Operations are also not included in this document's recommendations.

Transit

The *Alameda Countywide Multimodal Arterial Plan – Final Needs Assessment* (Fehr & Peers, February 22, 2016) memorandum identified four performance objectives related to transit. One performance measure for each of the following areas were developed – Transit Travel Speed, Transit Reliability, Transit Infrastructure Index and Pedestrian Comfort Index. These performance objectives/needs are summarized as follows:

- **Transit Travel Speed**: Achieve a PM peak hour transit speed greater than 75 percent of the automobile congested speed.
- **Transit Reliability**: Achieve a PM peak hour to non-peak hour transit speed ratio greater than 0.7.
- **Transit Infrastructure Index**: Achieve a High rating for network segments along major transit corridors or a minimum of Medium rating for segments along crosstown routes.
- **Pedestrian Comfort Index**: Achieve a Medium, High or Excellent rating along network segments with high priority transit to ensure adequate pedestrian access to and from bus stops.

Of the four needs listed above, ITS strategies are capable of at least partially satisfying the Transit Travel Speed and Transit Reliability categories. According to the Needs Assessment memorandum, 92 percent of high priority transit study network segments do not meet the Transit Travel Speed objective today. That same number goes down to 86 percent under Year 2040 Standard Forecasting Scenario conditions. Other existing conditions findings related to Transit Travel Speed include:

- The North County Planning Area, which has the majority of high priority transit corridors in the county, was observed to have the lowest PM peak hour transit speeds within the county as 50 percent of segments operate in the range of five to 10 MPH.
- The East County Planning Area was observed to have the highest PM peak hour transit speeds as transit operates in the 20 – 30 MPH speed range along 40 percent of transit serving segments.
- Transit operates in the 10 – 20 MPH PM peak hour speed range along 79 percent of transit serving segments in the Central County Planning Area and along 100 percent of segments in the South County Planning Area.

In the area of Transit Reliability, 45 percent of high priority transit study network segments do not meet the Transit Reliability objective today. These numbers increase to 63 percent under Year 2040 Standard Forecasting Scenario conditions. Overall the North and Central County Planning Areas have the greatest need for transit improvements. In 2015 AC Transit identified, as part of their *Major Corridors Study*, major corridors that are slated to receive significant improvements by 2040, most of which are listed in **Attachment A**. Most of the major corridors are in the North and Central County Planning Areas.

Automobile

The *Alameda Countywide Multimodal Arterial Plan – Final Needs Assessment* (Fehr & Peers, February 22, 2016) memorandum identified two performance objectives/needs in which both can be at least partially addressed through ITS strategies. These are summarized below:

- **Automobile Congested Speed**: Achieve a speed greater than 40% of the posted speed limit.
- **Automobile Reliability**: Achieve a vehicle-to-capacity ratio less than 0.8.

According to the same Needs Assessment memorandum, only eight percent of the roadway network segments do not operate at greater than 40 percent of the posted speed limit. This number doubles to 16 percent under Year 2040 Standard Forecasting Scenario conditions in which 2040 traffic volume estimates were taken into consideration along with the implementation of planned and funded roadway improvement projects. Other existing conditions findings related to Automobile Congested Speed include:

- The North County Planning Area was observed to have the lowest PM peak period automobile speeds within the county as 29 percent of segments operate at less than 20 MPH, compared to 12 percent or less in other Planning Areas.
- The East County Planning Area was observed to have the highest PM peak period automobile speeds as 14 percent of segments operate at greater than 40 MPH, compared to less than one percent in other Planning Areas.
- About 70 percent of segments in the Central and South County Planning areas operate at speeds between 20 – 30 MPH during the PM peak period.

Concerning Automotive Reliability, currently, 44 percent of the roadway network segments with high automobile priority do not meet the Automotive Reliability performance objective. This number is about 45 percent under Year 2040 Standard Forecasting Scenario conditions. The Needs Assessment evaluation indicates the Central County Planning Area has the greatest need for automobile improvements compared to the other three planning areas.

The Needs Assessment memorandum highlights the high priority roadway segments in the County that are located on the Study Network that do not meet the automobile performance objectives according to Fehr & Peers Year 2040 Standard Forecasting Scenario analysis. As shown in Attachment B, this memo has identified the 55 roadway network segments that warrant ITS consideration were chosen as the segments that do not meet the performance objectives. Factors taken into account in narrowing the list of roadway segments include: PM Peak Hour Vehicle Volumes in excess of 1,500, proximity to transit (i.e. BART), use as a commuter route, and use as a freeway reliever route. Residential arterials were avoided for the most part due to their relatively low traffic volumes, and instead focused on commercial areas of the county. These criteria were chosen based on professional judgement in order to focus on improvements to segments that are used the most. In order to focus on heavily used arterials, a minimum level of 1,500 vehicles during the PM peak hour was established as representative of high traffic volumes. Proximity to transit routes, either BART or bus, was selected to ease the transit between modes and because measures benefitting transit benefits more people.

4 | Auto and Transit ITS Recommendations

Using the transit corridors and automobile roadway segments identified as not meeting the performance objectives in Section 3, an assessment was developed for each corridor/segment's ITS infrastructure for three time frames – existing, 2020 and 2040. Below is a summary of each time frame:

- **Existing**: Assessment of the segment's ITS level today.
- **2020**: Assessment of the segment's ITS level in the year 2020, assuming all projects in construction or in the planning stages are completed.

- **2040**: Assessment of the segment's ITS level in the year 2040, assuming all ITS recommendations in this document are implemented in addition to the improvements included in 2020.

Table 2 provides a brief definition of each ITS level. **Figure 1 through Figure 5** summarize proposed ITS improvements, in addition to displaying the baseline ITS infrastructure (e.g. ITS infrastructure that exists today or is planned and funded for implementation in the near future). Detailed recommendations for each corridor and roadway segment are provided in **Attachment A** and **B** of this technical memorandum.

Quantifying the percent increase in speed directly resulting from implementation of ITS strategies is not easily accomplished. It is not possible to assign or determine a percent increase in vehicle speed resulting from certain ITS infrastructure improvements for a transit corridor or roadway segment. Many ITS strategies are put in place to enable the implementation of other strategies that can actually improve overall vehicle speed. For example, constructing a communications network that allows for the control of traffic signals from a central location will enable the deployment of time-of-day traffic signal synchronization or adaptive traffic control along a corridor which will directly improve average vehicle speed; as such, the implementation of a communications network by itself does not result in any operational improvements Other ITS strategies are designed to provide increased monitoring capabilities so transportation operators can deploy measures aimed at eliminating or reducing traffic congestion resulting from accidents and incidents. An example of this is the deployment of CCTV cameras or additional vehicle detection sensors. While the deployment of a CCTV camera or vehicle sensor alone will have no direct impact on improving average vehicle speed, the information provided to transportation operators would result in improved incident response and clearance times which would then result in improved average vehicle speed.

ITS strategies that are well documented as directly improving average vehicle speed are Transit Signal Priority (TSP), traffic signal synchronization, and adaptive traffic signal control. The specific percent improvement for each of these ITS strategies varies considerably from corridor to corridor and largely depends on the existing conditions for that specific corridor. For example, roadway segments that either have no traffic signal synchronization or signal timing plans that have not been updated regularly (every 3 to 5 years) will experience a higher percentage increase in vehicle speed compared to those corridors where signal timing is revised regularly. It is estimated that the following range of vehicle speed increases are possible for the following ITS strategies and are based on the industry's long history of successfully planning, designing, deploying and evaluating these types of projects.

- Transit Signal Priority (TSP) – 10% to 15%
- Time-of-Day Traffic Signal Synchronization: 5% to 20%
- Adaptive Traffic Signal Control: 5% to 30%

Attachments A and **B** provide draft proposed ITS improvements along each transit corridor and roadway segment as well as assessed infrastructure levels for the years 2020 and 2040. The levels assigned to each segment for the existing, Year 2020, and Year 2040 are based on the information gathered throughout this project by the consulting team, ACTC and other stakeholders as well as professional judgement. Using the four levels described below, each segment listed in **Attachments A** and **B** was categorized according to what is in place in the field today, what is in the current project pipeline (Year 2020), and what is recommended to be deployed in addition to what is in the project pipeline (Year 2040).

Table 2 – ITS Level Summary

LEVEL	ITS STRATEGIES
0	No ITS infrastructure in place. There is no ability to remotely monitor or manage traffic signals.
1	Field-to-Center communications are in place. Ability to remotely monitor and manage traffic signals exists.
2	Level 1 plus CCTV cameras, Time-of-Day signal timing, adaptive signal control, Transit Signal Priority (TSP)
3	Level 2 plus Changeable Message Signs (CMS), Trailblazer Signs (TBS), Connected and Autonomous Vehicle (CAV) technologies.

5 | Institutional Coordination for Implementation

The intent of this section is to provide a framework that Alameda CTC and local agencies can use in developing a regional/multi-jurisdictional ITS operations program focused on local arterials. Generally, the goals of such a program are to:

- Improve multi-jurisdictional traffic signal coordination, including the use of signal timings that provide superior response to or adapt to traffic conditions;
- Improve ability to respond to traffic incidents;
- Improve ability to manage traffic flows associated with incidents and congestion on area roadways;
- Better integrated transportation system that considers multiple travel modes; and
- Provide improved and more reliable real-time traveler information.

Existing Multi-Jurisdictional ITS Project/Program Agreements

There are currently a number of existing and in-progress ITS projects and programs that involve multiple stakeholders that include MTC, Caltrans, AC Transit, Alameda CTC, and various local municipalities within Alameda County. For each project/program, an overview of the institutional arrangements are provided below with a focus on the issues of ownership of project improvements, on-going maintenance, and operational control. This presents an overall picture of how various Bay Area agencies within Alameda County are currently working together on large corridor ITS-related projects and programs that span multiple jurisdictions.

PROJECT/PROGRAM	I-80 INTEGRATED CORRIDOR MANAGEMENT (ICM)
Agreement	Memorandum of Understanding (MOU)
Parties to Agreement	Caltrans, Alameda CTC, AC Transit, Cities of Oakland, Emeryville, Albany, and Berkeley (*and other agencies outside Alameda County*)
General Framework	Defines overall project; project governance; operational principles; equipment ownership and maintenance; and roles and responsibilities of each party.
Ownership	All equipment within each agency's right-of-way are owned by that agency. For example, all equipment within the boundaries of Oakland are owned by Oakland.
Maintenance	All equipment within each agency's right-of-way are maintained by that agency. Exceptions include traffic signals along San Pablo Avenue (SR 123) in Oakland and Berkeley where Caltrans has delegated operations and maintenance responsibilities of those signal to each respective city. For cities within Alameda County, Alameda CTC provides funding for maintenance of ICM equipment.
Operations	Caltrans is primarily responsible for operation during an incident condition in accordance with an Incident Response Plan. During non-incident conditions, each agency is responsible for operations of equipment within their right-of-way.

PROJECT/PROGRAM	I-880 INTEGRATED CORRIDOR MANAGEMENT (ICM)
Agreement	Memorandum of Understanding (MOU)
Parties to Agreement	MTC, Caltrans, City of Oakland, and City of San Leandro
General Framework	Defines overall project; project governance; operational principles; equipment ownership and maintenance; and roles and responsibilities of each party.
Ownership	All equipment within each agency's right-of-way are owned by that agency. For example, all equipment within the boundaries of San Leandro are owned by San Leandro.
Maintenance	All equipment within each agency's right-of-way are maintained by that agency, with the exception of the trailblazer signs. The trailblazer signs will be maintained by MTC.
Operations	Caltrans is responsible for operation during an incident condition in accordance with an Incident Response Plan. During non-incident conditions, each agency is responsible for operations of equipment within their right-of-way with the exception of trailblazer signs.
PROJECT/PROGRAM	EAST BAY SMART CORRIDOR (SAN PABLO AVENUE)
Agreement	Memorandum of Understanding (MOU) Operations and Maintenance (O&M) Agreement
Parties to Agreement	Caltrans, Alameda CTC, Cities of Oakland, Emeryville, Albany, and Berkeley (*and other agencies outside Alameda County*)
General Framework	Defines project governance; operational principles; equipment ownership and maintenance; and roles and responsibilities of each party.
Ownership	All equipment within each agency's right-of-way are owned by that agency. For example, all equipment within the boundaries of Berkeley are owned by Berkeley.
Maintenance	All equipment within each agency's right-of-way are maintained by that agency. Exceptions include traffic signals along San Pablo Avenue (SR 123) in Oakland and Berkeley where Caltrans has delegated operations and maintenance responsibilities of those signal to each respective city. Alameda CTC provides funding for maintenance of ATMS field equipment.
Operations	Caltrans is responsible for operation during an incident condition.
PROJECT/PROGRAM	AC TRANSIT LINE 97 TRANSIT PERFORMANCE INITIATIVE (TPI)
Agreement	Memorandum of Understanding (MOU) Cooperative Agreement (*Currently Under Development*)
Parties to Agreement	MTC, Caltrans, AC Transit, Alameda County, Cities of Hayward, San Leandro, & Union City
General Framework	Defines overall project; project governance; equipment ownership and maintenance; and roles and responsibilities of each party.
Ownership	All equipment within each agency's right-of-way are owned by that agency. For example, all equipment within the boundaries of San Leandro are owned by San Leandro. Adaptive central system equipment will be jointly owned by Hayward, San Leandro, and Alameda County. (*Tentative*)
Maintenance	All equipment within each agency's right-of-way are maintained by that agency. The adaptive central system equipment will be maintained by Hayward and San Leandro. (*Tentative*)
Operations	Adaptive signal control operational parameters will be jointly determined by Hayward, San Leandro, and Alameda County. (*Tentative*)
PROJECT/PROGRAM	SILICON VALLEY INTELLIGENT TRANSPORTATION SYSTEM (SV-ITS)
Agreement	Memorandum of Understanding (MOU)
Parties to Agreement	MTC, Caltrans, City of Fremont (*and other agencies outside Alameda County*)
General Framework	Defines overall project; project governance; operational principles; and roles and responsibilities of each party.
Ownership	All equipment within each agency's right-of-way are owned by that agency. For example, all equipment within the boundaries of Fremont are owned by Fremont.
Maintenance	All equipment within each agency's right-of-way are maintained by that agency.
Operations	Each agency is responsible for operations of equipment within their right-of-way.

Based on these current ITS projects/programs in Alameda County, the current trend thus far points towards a more distributed form of coordination where overall decision making and authority rests with the individual agencies, with some minor exceptions. These trends for ownership, maintenance, and operations can generally be summarized as follows:

- **Ownership**: The trend for ownership generally follows that any equipment and/or improvements deployed by a particular project/program that are located within a particular agency's right-of-way are owned by that agency. There does not appear to be any situations to date, where any physical improvements deployed within one agency is owned by another.
- **Maintenance**: The trend for maintenance is similar to that for ownership. Generally, maintenance responsibilities for any equipment and/or improvements deployed within a particular agency are maintained by that agency. There are some exceptions where the maintenance is performed by another agency or the cost of maintenance is reimbursed by another agency. These exceptions are typically exhibited with local cities and usually only for some elements of the overall improvements such as message signs or CCTV cameras.
- **Operation**: The trend for operation appears to be the most fluid with a shift towards a more centralized format. With the more recent programs (I-80 and I-880 ICMs), there are provisions for one agency (Caltrans) to operate equipment, such as message signs and CCTV cameras, that are located in another agency (local cities). However, the inter-jurisdictional operations of traffic signals continues to be more restrictive. It is not typical for one agency to have day-to-day operational control of the traffic signals in another agency. But this is shifting as well with the two ICM programs where these will be the first instances where one agency (Caltrans) will be allowed to change the operation of traffic signals owned by local cities that are part of the ICM program. It should be noted that the changes are limited, well pre-defined, and pre-approved by the local cities and implemented only during an incident situation.

Interjurisdictional Coordination

The collaboration between Caltrans, MTC, Alameda CTC, local agency transportation departments, transit agencies, and other stakeholders is key to addressing regional mobility issues on arterials that span multiple jurisdictions. Based on our research, the MOU's described in the previous section are the only formal or informal coordination arrangements between agencies in the County in the areas of ITS and traffic signal operations. Iteris recommends the project stakeholders seek to partner with their neighbors on a formal or informal basis whenever possible. By working together, partner agencies can achieve significant benefits by addressing arterial operational issues from a system level perspective.

For any interjurisdictional effort to be successful, there needs to be a lead agency to serve as the project/program champion. There are a number of different organizational concepts that can be utilized ranging from where the lead agency is responsible for only providing the funding to partner entities to develop-operate-maintain the program (most distributed decision-making and authority) to where partner entities consolidate development-operation-maintenance of the program under the direction of the lead agency (most centralized decision-making and authority). The development of the organizational structure will need to address the needs listed below. These needs can and should be addressed in whatever order makes the most sense to each agency.

- Establishment of a formal reporting structure;
- Roles and responsibilities of participating agencies;
- Authority of any regional entity;
- Develop cost sharing arrangements;
- Develop structure for day to day operations; and

- Develop performance measures for continued assessment of the project/program.

The exact nature of the organizational structure will largely be dependent on the outcomes to the following questions:

- Who is responsible for purchasing and deploying any necessary communications and field equipment?
- Who has ownership of which pieces of equipment (and/or software licenses) deployed?
- Who is responsible for testing and inspecting any field equipment deployed?
- Who will develop the timing/operational plans?
- Who will implement the timing/operational plans?
- Who will perform project evaluation?
- Who is responsible for O&M of the field equipment and/or the timing plans?
- Who will be notified if timing plans need to be changed, are there restrictions on when timing plans can be changed, and what form of consensus is needed to implement the change?

The outcomes to these questions can typically be addressed through the development of a Concept of Operations report for the project/program. The Concept of Operations is a valuable tool that describes the operation of the system being developed from the various stakeholder viewpoints. It documents the user's requirements for ultimate system operations. It helps to identify what type of agreement will be more appropriate for implementation of and effective operation of a project or program considering the environment it will operate and the stakeholders involved.

- **Memorandum of Understanding (MOU)** – An MOU is generally established at the onset of the project/program to define the organizational structure and outline the basic principles and guidelines for how different partner agencies will work together. The MOU should describe the purpose and intent of the project/program and the relationships between partner agencies, as well as the administrative governance of the project/program. The MOU can be used to establish a Technical Advisory Committee (TAC) to address technical and day-to-day operational issues and a Policy Advisory Committee (PAC) to address program level issues and resolve issues that cannot be addressed at the TAC level. The MOU is generally a non-binding agreement.
- **Cooperative Agreement** – Cooperative agreements are similar in concept to the MOU but are typically legally binding contracts between partner agencies. The cooperative agreement can be used to further define each partner agency roles and responsibilities, obligate each partner agency to a financial commitment to the project/program, and define program/project product ownership.
- **Project Agreement** – A project agreement is typically used to initiate specific improvements within the framework of the larger overall program. Project agreements are typically needed in larger programs that may implement improvements over multiple phases and over various geographic areas. Typically, a project agreement is specific to particular project to be implemented with the larger program and may only be between a subset of all the partner agencies that are part of the program. Project agreements are typically legally binding.
- **Funding Agreement** – Funding agreements can be utilized to transfer funds between partner agencies and are typically a mechanism to facilitate cost sharing. This agreement may or may not be needed depending on the structure of any executed cooperative agreements or project agreements.
- **Operations and Maintenance (O&M) Agreement** – An O&M agreement is utilized to establish on-going operations and maintenance of the infrastructure and improvements

built and deployed by the project/program. An O&M agreement establishes the minimum level of maintenance, which agency(ies) will be responsible for on-going maintenance, cost-sharing of maintenance, the agency(ies) responsible for operating the improvements, and establish rules and protocol for operating the improvements and requesting changes in operation. This is typically a legally binding agreement.

- **Maintenance Agreement (Caltrans)** – This agreement is specific to address Caltrans facilities, such as a traffic signal along a state highway or at an interchange, that are located within a particular municipality. There may be situations where there is an identified need for a local municipality to take over operations and maintenance of a Caltrans signal. In this case, a Caltrans Maintenance Agreement would be needed for Caltrans to delegate authority of operations and maintenance to the local municipality. This is a legally binding agreement and typically also includes cost-sharing of the maintenance component.

Technical Integration Approach

With a strong foundation of cooperation between the project stakeholders in place, the high level technical approach to integrating the separate components and subsystems that comprise an ITS project is consists of the following:

- Following FHWA Systems Engineering guidelines in order to ensure what is deployed meets the original intent of the stakeholders. Additionally, ITS projects that include federal funding is required to follow FHWA's Systems Engineering guidelines. By doing so from the very beginning of a project or program (even if federal funds are not used initially) will increase the chances of receiving federal funds should the local agency and/or ACTC elect to apply at a later time.
- Selecting system components (hardware, software and firmware) that meets or exceeds the system requirements.
- Establishing robust and secure communications between the field devices and the owning agency's traffic management staff.
- Establishing robust and secure communications between all the stakeholder agencies that require access to the information and data provided to and/or from another agency's field devices.
- Properly configuring all network devices and field devices in accordance with the information sharing policies outlined in any applicable interjurisdictional agreements.
- Establishing acceptance testing plans and procedures at the unit, subsystem and system level, then meticulously executing those same plans and procedures.
- Properly documenting all system components in accordance with FHWA guidelines.
- Properly training all agency staff on the operation and maintenance of the system.

Maintenance Considerations

An Achilles heel of many ITS programs nationwide is maintaining the systems that are designed, constructed, and deployed using capital funds. There are two main factors behind this issue – staff training and funding. In the first few years after a project is deployed and accepted most system components are under an extended manufacturer's warranty that was included with the original purchase using capital funds. As a result, the maintenance needs are relatively small and the training received by agency staff is therefore not heavily utilized. In a lot of cases by the time system components begin to fail or require troubleshooting the staff's maintenance skills have either eroded through non-use or have disappeared through staff turnover. This situation results in the public realizing no benefit or less of a benefit from the capital investment made to deploy the system.

While there are a plethora of state and federal grant programs that provide capital funds to build a project, most local agencies are expected to pay for the ongoing maintenance themselves by using their own staff, who may or may not be adequately trained and frequently have many other responsibilities, or outsourcing the maintenance to a third party provider. Paying for the third party provider or in-house staff time is frequently done from the agency's general fund whose health is directly related to the amount of tax revenues collected in any given year.

The following general course of action is recommended regarding maintenance of ITS infrastructure:

- Include recurring Operations & Maintenance costs into the overall cost structure of any ITS project. There are industry standards for the useful life, replacement cost and annual maintenance cost for every ITS field device type. It is recommended that using those standards to calculate the annual maintenance and replacement cost for units that reach the end of their useful lives.
- Determine the maintenance responsibilities of each stakeholder agency so all parties have a clear understanding of their obligations in terms of labor and finances at the beginning of every project.
- Include Service Level Agreement provisions in all agency MOU's and cooperative agreements so all stakeholder agencies understand what is expected in terms of system uptime. These Service Level Agreements would be included in any contracts with third party maintenance providers.
- Determine the appropriate level of Operations & Maintenance funding to be provided by ACTC and the local agencies. It is envisioned that an arrangement where the local agencies monitor and maintain the material condition of the ITS infrastructure in their right-of-way and ACTC assists each agency to forecast annual operations and maintenance costs and determine the combination of local agency and ACTC funds that will finance it.

6 | Next Generation Transportation Technology

V2I – Vehicle to Infrastructure

Transportation agencies, along with other public and private sector entities, must prepare for emerging technologies that will fundamentally change mobility. Looking ahead, cars, trucks, buses, the roadside, and personal mobile devices will all talk to each other. They will exchange information that will enable "connected vehicle" (CV) applications to be deployed to improve safety, mobility, the environment, and support agency efficiency. There are two main aspects of connected vehicle infrastructure, vehicle-to-vehicle (V2V) interactions and vehicle-to-infrastructure (V2I) interactions. V2V applications and advancement are being led by the automotive industry and moving ahead independent of public sector transportation agencies and will not be the focus of this memorandum. Instead, the focus will be on the V2I applications with particular emphasis on what the County needs to do to be prepared for the "I" in V2I.

V2V – Vehicle to Vehicle

There are four main types of connected vehicle applications: Safety, Mobility, Environmental, and Support. Connected vehicle safety applications are designed to increase situational awareness and reduce or eliminate crashes. Connected vehicle mobility applications provide a connected, data-rich travel environment. These communications would support driver advisories, driver warnings, and vehicle and/or infrastructure controls, by capturing real-time data from equipment located on-board vehicles and within the transportation infrastructure. The data are transmitted wirelessly and used by transportation agencies in a wide range of dynamic, multi-modal applications to manage the transportation system for optimum performance. These applications would both generate and capture environmentally relevant real-time transportation data and use this data to support and facilitate green transportation choices, thus reducing the environmental impacts of each trip, and serving the final two types of CV applications.

There are close to 100 individual connected vehicle applications that are categorized into each of the four main types. For the Mobility and Environmental types, the applications are further organized into bundles. For example, the Mobility applications include six bundles: Enable Advanced Traveler Information Systems (Enable ATIS); Freight Advanced Traveler Information Systems (FRATIS); Integrated Dynamic Transit Operations (IDTO); Multimodal Intelligent Transportation System (MMITS); Response, Emergency Staging and Communications, Uniform Management, and Evacuation (RESCUME); and Intelligent Network Flow Optimization (INFLO). The Connected Vehicle Reference Implementation Architecture (CVRIA) sponsored and led by the United States Department of Transportation Intelligent Transportation Systems Joint Program Office (USDOT ITS JPO) provides a list and detailed description of each CV application. The CVRIA can be found at:
http://www.iteris.com/cvria/index.html

Transportation Agency CV Opportunities

As the steward of the nation's roadways, state and local DOT's as well as County MPO's such as Alameda CTC have a responsibility for ensuring the transportation infrastructure contributes to improving safety, mobility and air quality. Connected vehicle networks can positively impact all three areas.

According to the Insurance Institute for Highway Safety Highway Loss Data Institute (IIHS-HLDI), a total of 32,765 people died in motor vehicle crashes in 2014. The U.S. Department of

Transportation's most recent estimate of the annual economic cost of crashes was $242 billion dollars.[1] Vehicle-to-Vehicle and Vehicle-to-Infrastructure data transmissions supporting CV safety applications can provide drivers with information such as roadway hazards or inclement weather conditions. This additional information will improve driver situational awareness and eliminate some crashes. For the last 40 years the U.S. DOT has successfully focused on surviving crashes through requiring the use of seat belts and mandating air bags in all new vehicles. Soon government agencies can expand this into avoiding crashes altogether.

According to the Texas Transportation Institute's 2015 Urban Mobility Scorecard, travel delay due to traffic congestion caused drivers to waste more than three million gallons of fuel and kept travelers stuck in their cards for nearly seven billion extra hours – 42 hours per rush-hour commuter. This equates to a total cost of $160 billion, or $960 per commuter. V2I applications and anonymous information from passenger wireless devices have the potential to provide transportation agencies with significantly clearer picture of what is actually happening on the roadways. Obtaining actionable traffic, transit and parking data in real-time will allow public agencies to manage their infrastructure in the most efficient manner possible.

Automobiles, trucks and buses are major sources of greenhouse gas (GHG) emissions. Motor vehicles that idle or move in a stop-and-go manner as a result of traffic congestion are some of the worst mobile sources of GHG emissions. Connected Vehicle applications will generate and collect environmentally relevant real-time transportation data that can be used by transportation agency staff to manage the transportation network in a more environmentally sensitive manner.

Steps to V2I Deployment

The process by which CV infrastructure and applications will be planned and implemented by agencies is similar to that for any other transportation infrastructure and is generally an extension of existing ITS practices. The primary distinction is that the full effect of the CV infrastructure operation will grow and be realized over time as CV-equipped vehicles enter and multiply in the transportation environment. These vehicles will provide data to the system and, when equipped with CV applications, will be able to leverage information provided from the infrastructure. While the transportation agency has little control over the introduction of CV-equipped vehicles into the transportation environment (aside from supporting State-level regulations or legislation), the National Highway Traffic Safety Administration (NHTSA) is expected to issue regulations this year to require automobile manufacturers to equip new vehicles with basic CV equipment accommodating the Basic Safety Message (BSM) of speed and direction.

CV Needs Assessment

It is recommended that the first step in CV deployment is to identify the agency's needs and, where possible, match these needs to appropriate deployment opportunities. The CVRIA developed by US DOT ITS JPO identifies and provides descriptions of potential connected vehicle applications and NCHRP 03-101 Deployment Plan provides a tool for assessment of opportunities.

While many of the CV applications are intended to address very local operational problems, the benefits of the CV environment are much broader. It will be important to develop institutional awareness and support for local and regional deployments at an early stage as awareness and cooperation within and between agencies will be necessary to deploy infrastructure and applications

[1] IIHS-HLDI 2014 Yearly Snapshot, http://www.iihs.org/iihs/topics/t/general-statistics/fatalityfacts/overview-of-fatality-facts/2014.

that are useful to vehicles operating across jurisdictions. In this respect, local agencies consulting with both Alameda CTC and MTC is highly recommended as these organizations are either actively developing CV application deployment plans themselves or know of other local agencies who are doing the same.

Since the applications require connected vehicles to be present within the fleet, deployment assessment will need to address the prevalence of enabled vehicles within the population. While many vehicles are already capable of some level of connectivity, growth of DSRC and cellular connectivity within the target vehicle fleets will directly impact both the timing and effectiveness of infrastructure deployment.

Alameda CTC's CV Needs Assessment should rely upon the Multimodal Arterial Plan, the Goods Movement Plan and the Countywide Transit Plan as a basis for both identifying the transportation system needs and justifying the CV applications to satisfy those needs. The needs may be capital infrastructure, operations and maintenance, policy, or similar. Once the needs are identified, as assessment of the various CV application(s) can be performed that fulfill those needs. As an example, the CV application bundle that stands out to meet many of the needs, goals, and objectives of this multimodal arterial plan is the MMITS. MMITS is a next-generation traffic signal system that seeks to provide a comprehensive traffic information framework to service all modes of transportation that is focused at the arterial roadway level. The MMITS application bundle seeks to improve mobility along signalized corridors using advanced communications and data to facilitate the efficient travel of passenger vehicles, pedestrians, transit, and freight and include such applications as Intelligent Traffic Signal System (I-SIG), Freight Signal Priority (FSP), Mobile Accessible Pedestrian Signal System (PED-SIG), and Transit Signal Priority (TSP).

Application Evaluation

As part of pre-deployment planning, it will be appropriate to look at cost-benefit analyses of CV applications especially when comparing to traditional ITS solutions; however, many CV applications lack adequate cost-benefit information. To help with this, agencies should consider a local demonstration pilot CV project along one corridor. The pilot project would help identify the benefits and/or costs of future deployment projects as well as gaining insight into the technologies being implemented. The benefit estimates will be a large part of the overall acceptance of V2I into the City's current ITS system.

It should be noted that several state and local agencies are in the process of deploying connected vehicle technology pilot demonstrations in conjunction with the U.S. DOT, and the Research and Innovative Technology Administration's (RITA) Affiliated Test Bed initiative is coordinating information on these pilot demonstrations and testing opportunities. The cost-benefit analysis of these pilot deployments may be used by US DOT pilot participants to evaluate their own initial deployments.

Planning

This initial needs assessment and application evaluation should be followed by a planning stage which would culminate in the development of a Connected Vehicle Strategic Plan. This would provide the mechanism to understand the County's needs, goals and objectives; identify the specific CV applications to meet those needs, goals, and objectives; develop a deployment plan for each identified CV application; develop cost estimates for development, operations, and maintenance; identify needed stakeholders and partnerships; identify funding strategies; and identify performance based measurements so that benefit-costs can be determined to assess how each application meets the needs and achieves the goals and objectives. At this stage, a five to seven year plan is recommended.

Once an agency completes their CV Strategic Plan and begins to deploy we recommend following process outlined in FHWA's Systems Engineering Guidebook for ITS which can be found at https://www.fhwa.dot.gov/cadiv/segb/. Each project will have a Systems Engineering Management Plan (SEMP), Concept of Operations (CONOPS) and System Requirements documents developed to guide the detailed design and deployment. Unit, subsystem and system acceptance testing would also be conducted in accordance with FHWA's guidelines.

Included in the planning process is the development of a deployment plan. The deployment plan should integrate performance measurements to quantify the benefit-cost of each CV application deployment and establish prioritization of CV application roll out.

Deployment Considerations

Given that public agencies will almost exclusively concentrate on V2I deployments, there are key distinguishing characteristics to be considered in the project planning, design, and deployment phases:

- V2I equipment deployments may vary between project sites depending on the CV applications to be supported.
- Where DSRC radios are to be deployed, each DSRC radio will be licensed for the site and the frequency of the radio will vary depending on the conditions.
- Project deployments will depend on the availability of supporting systems such as security and credentials monitoring which may be provided by external service entities.
- CV projects will require sufficient (private) vehicle deployments to operate and measure the performance of the system. Equipped-vehicle penetration level requirements will depend on the CV applications needed and implemented.
- CV and V2I deployments will also depend on the eventual development of design and special provisions standards. These standards are currently being developed by FHWA and USDOT. They are still in the final approval process and expected to be released sometime in 2016.

Actions that local agencies can take to prepare for the widespread deployment of Connected Vehicles and eventually Autonomous Vehicles include providing digital infrastructure, considering systems for data capture and exploitation, preparing existing infrastructure, cyber security, operational leadership and partnerships.

Digital Infrastructure

Many of the benefits from Connected and Autonomous Vehicles (CAV's) rely, at least partially, on connectivity between the vehicle and the wider infrastructure. Wireless networks in urban areas will allow vehicles to communicate with traffic management systems in real-time, sharing information such as signal phasing, signal timing and live traffic conditions. This information will allow CAV's to optimize their speed and routing in order to reduce travel times and congestion.

Transportation agencies play an important role in delivering this connectivity by either putting in place the required telecommunications networks and/or making their traffic data and telecommunications networks available for integration with third parties in a secure manner.

Data Capture and Exploitation

CAV's are expected to generate an extremely large amount of detailed data on how, when and where people move about the County. The value of this data is quite high as many transportation agencies around the country are trying to tap data reserves from human driven vehicles. CAV's provide an additional opportunity to capture and exploit this data in order to improve transportation networks and better understand how people move about the County. Ensuring transportation agencies have access to the appropriate datasets and can make sense of it is key.

Infrastructure

Transportation agencies should consider how their infrastructure assets such as traffic signals, lamp posts, signs, roads and bridges are prepared to accommodate CAV's. Of primary concern is determining whether the current infrastructure can support the wireless connectivity required for CAV's. This is particularly important for traffic signals and related equipment (e.g., Emergency Vehicle Preemption systems, Transit Signal Priority systems). As infrastructure is replaced or renewed through maintenance and improvement, agencies should evaluate whether to deploy similar replacements or upgraded replacements that are capable of supporting CAV's. At a higher level, agencies should consider the impact of CAV's on new transportation schemes and modes. For example, increased use of CAV's may negate the need for building a new or expanding an existing road or parking facility.

Cyber Security

Acceptance and adoption of CAV's and related technologies is predicated on the safety and security of the vehicles. Data and information must be protected from external and internal attacks that will inevitably occur and the "Internet of Things" (IoT) is introduced to the County's transportation network. Simply put, transportation agencies must maintain a real-time understanding of the security of the network, and the threats, mitigations and weaknesses that exist 24/7. These costs should be factored into the overall operations and maintenance budgets as well. The days of closed traffic and ITS telecommunications networks are rapidly coming to an end. The same vigilance that is put towards an agencies Wide Area Network (WAN) is required for any ITS network.

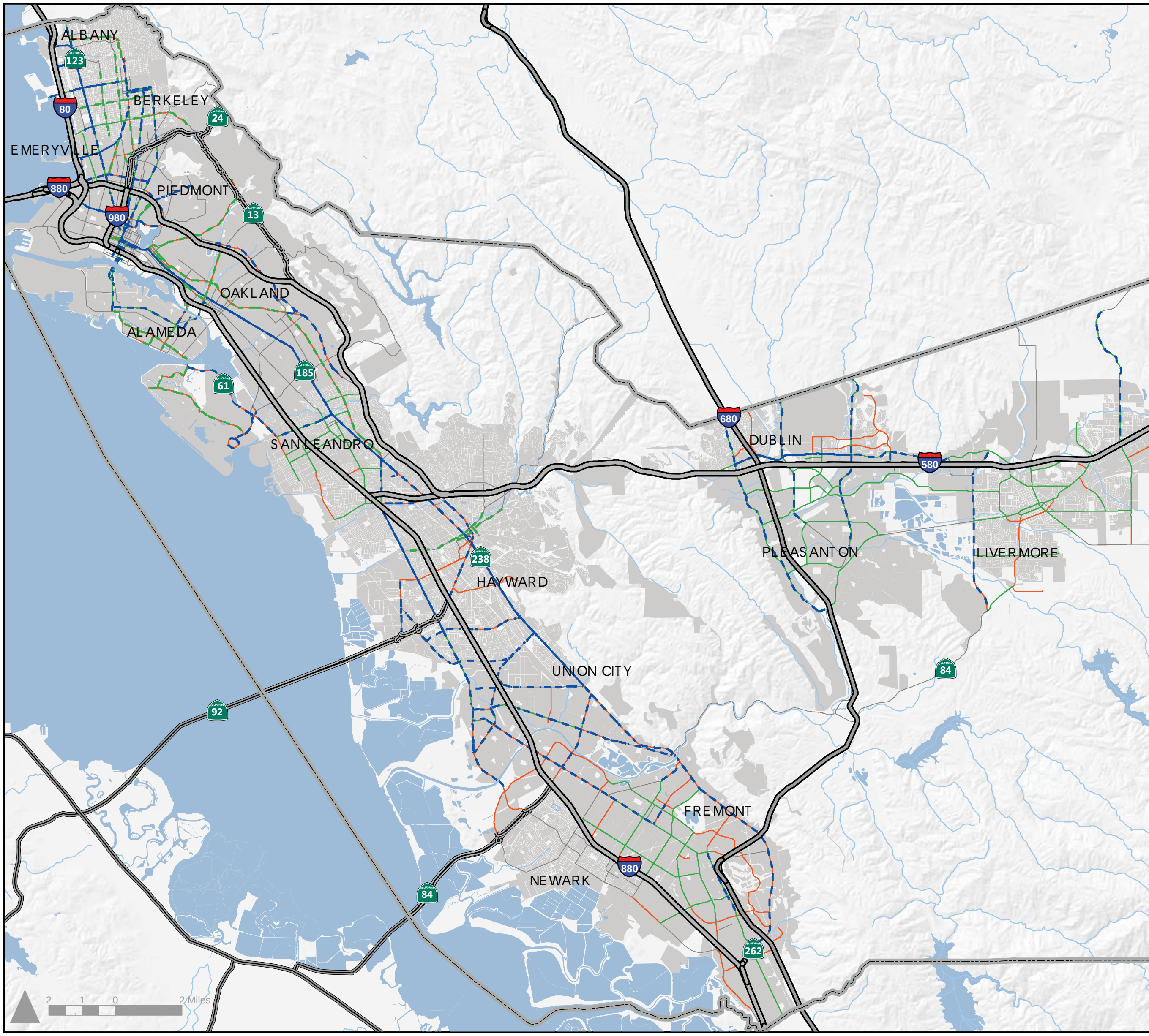
Leadership

Transportation agencies should consider their role in leading CAV development from an operational perspective – challenging themselves to take the right technical and strategic view across their organization. New roles, such as chief digital officer or emerging technical divisions, which are becoming common in the private sector, must also be considered of relevance. Los Angeles has recognized this, appointing a transportation technology advisor position within the city's Department of Transportation, with a remit to consider the impact of new car and rideshare services, as well as planning for the arrival of CAV.

Partnerships

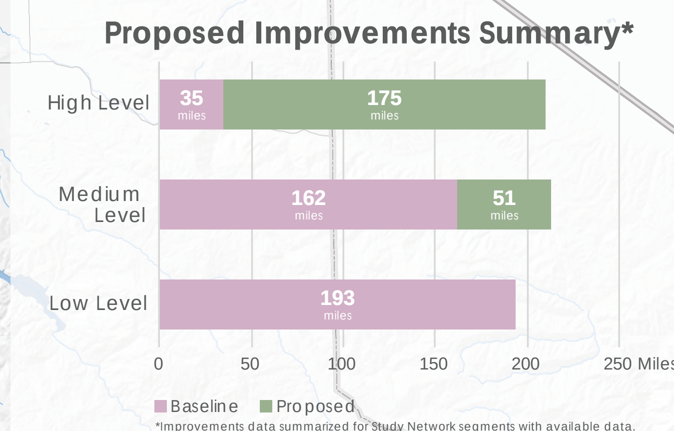
Transportation agencies should consider positioning themselves in order to maximize the potential for CAV technology at an early stage. One approach would be to partner with car manufacturers and other companies developing CAVs to provide opportunities for testing and development. Cities such as San Francisco and Las Vegas are becoming known for their relationship with CAV developers, giving them competitive advantages. Uber's decision to move 3,000 of their employees to downtown Oakland is one opportunity for Alameda County and the City of Oakland to establish a similar reputation.

Attachments
Figure 1 – Proposed Countywide ITS Network Improvements
Figure 2 – ITS Network Proposed Improvements – North County
Figure 3 – ITS Network Proposed Improvements – Central County
Figure 4 – ITS Network Proposed Improvements – South County
Figure 5 – ITS Network Proposed Improvements – East County



Considered ITS network improvements include:

- **Low Level of ITS Infrastructure** – generally corresponds to the ability to remotely monitor and manage field devices from a central location (e.g., Transportation Managment Center). Traffic signals along a corridor are interconnected and allow communication back to a TMC where there is a central system to actively manage field devices.
- **Medium Level of ITS Infrastructure** – corresponds to everything described above plus the additional ability to visually monitor and/or react to traffic conditions in real time from a central location. This includes having devices such as closed-circuit television (CCTV) cameras, adaptive signal timing controls, and/or transit signal priority controls.
- **High Level of ITS Infrastructure** – corresponds to everything described above plus the additional ability to actively inform and influence traffic flow in real-time from a central location. This includes devices such as changeable message signs or any connected vehicle (vehicle to infrastructure) capabilities.



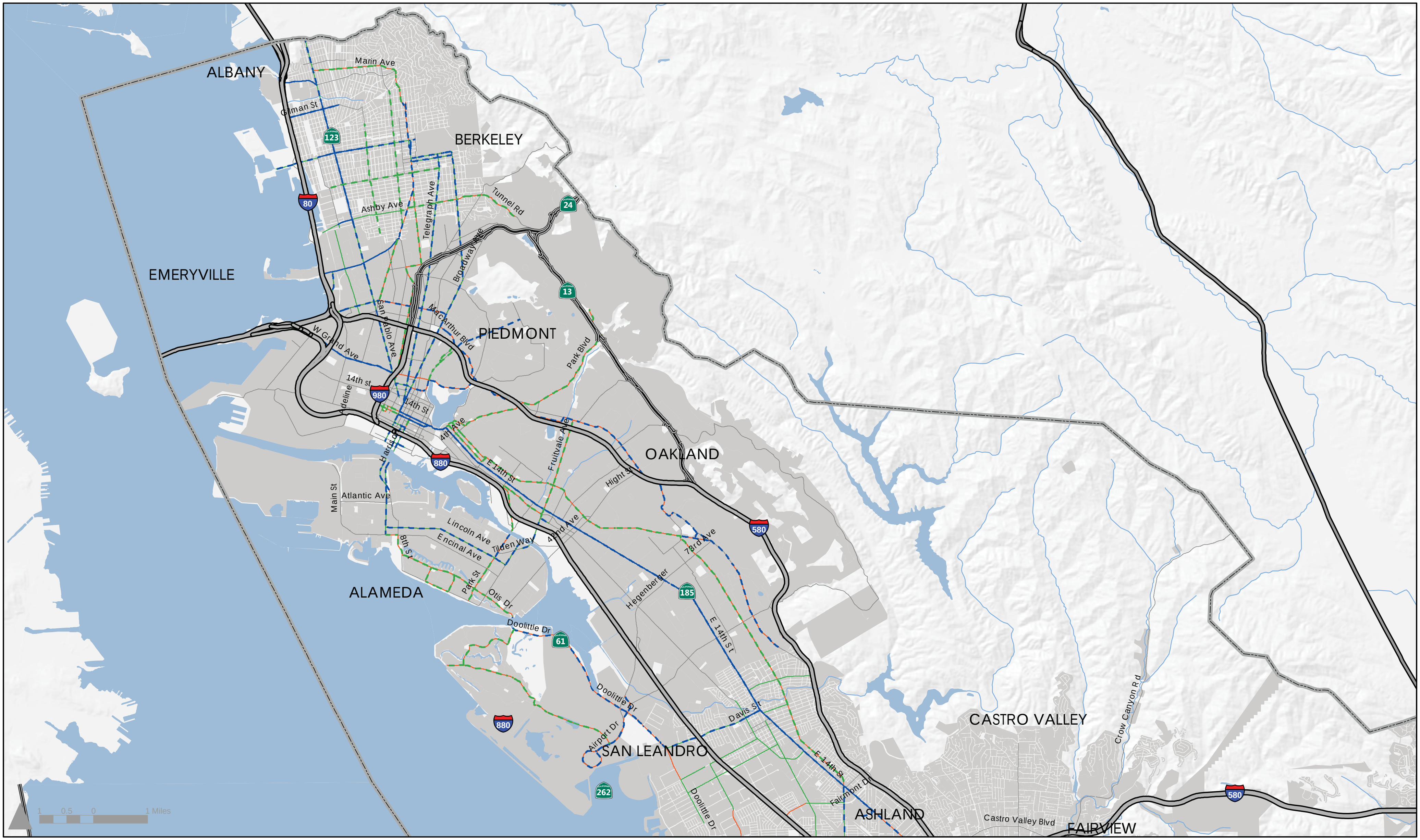
Legend: Automobile Network Improvement

- Baseline High Level of ITS Infrastructure
- Baseline Medium Level of ITS Infrastructure
- Baseline Low Level of ITS Infrastructure
- Proposed High Level of ITS Infrastructure
- Proposed Medium Level of ITS Infrastructure
- Proposed Low Level of ITS Infrastructure
- Urban Area

ALAMEDA County Transportation Commission

Figure 1

Proposed Countywide ITS Network Improvements



Legend

- Baseline High Level of ITS Infrastructure
- Baseline Medium Level of ITS Infrastructure
- Baseline Low Level of ITS Infrastructure
- Proposed High Level of ITS Infrastructure
- Proposed Medium Level of ITS Infrastructure
- Proposed Low Level of ITS Infrastructure
- Urban Area

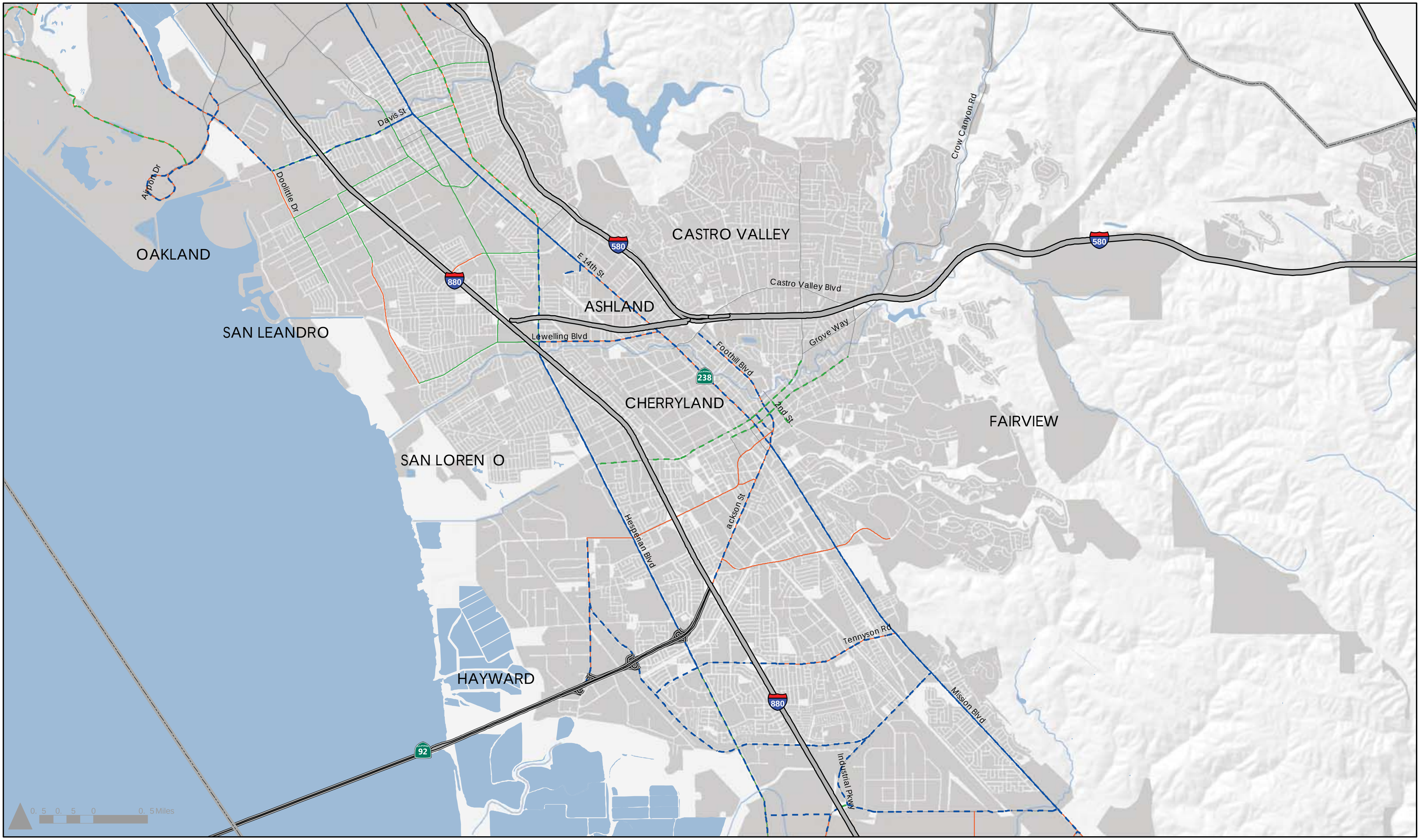
ALAMEDA County Transportation Commission

Alameda Countywide Multimodal Arterial Plan

North County

Figure 2

ITS Network Proposed Improvements



Legend

- Baseline High Level of ITS Infrastructure
- Baseline Medium Level of ITS Infrastructure
- Baseline Low Level of ITS Infrastructure
- Proposed High Level of ITS Infrastructure
- Proposed Medium Level of ITS Infrastructure
- Proposed Low Level of ITS Infrastructure
- Urban Area

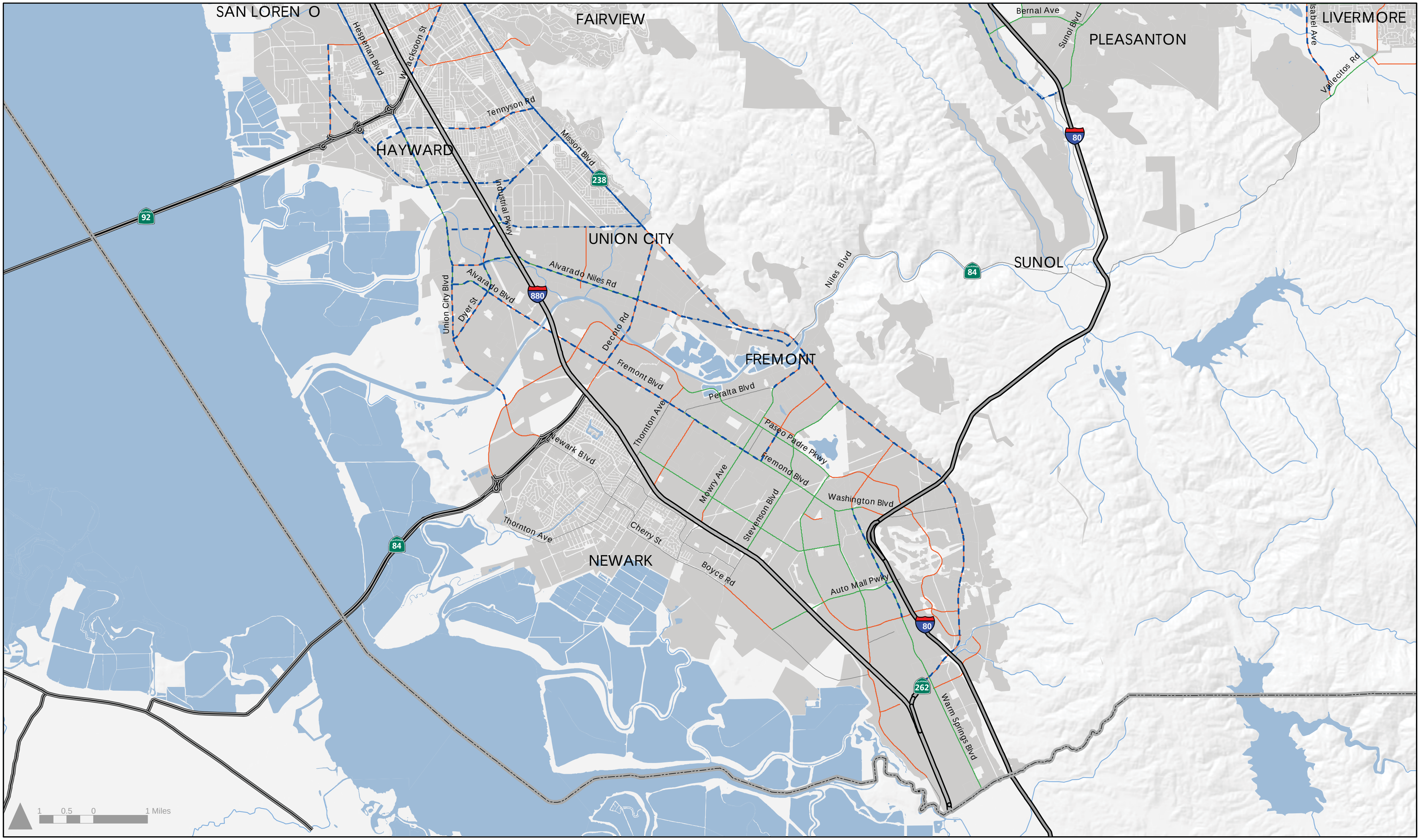
ALAMEDA County Transportation Commission

Alameda Countywide Multimodal Arterial Plan

Central County

Figure 3

ITS Network Proposed Improvements



Legend

- Baseline High Level of ITS Infrastructure
- Baseline Medium Level of ITS Infrastructure
- Baseline Low Level of ITS Infrastructure
- Proposed High Level of ITS Infrastructure
- Proposed Medium Level of ITS Infrastructure
- Proposed Low Level of ITS Infrastructure
- Urban Area

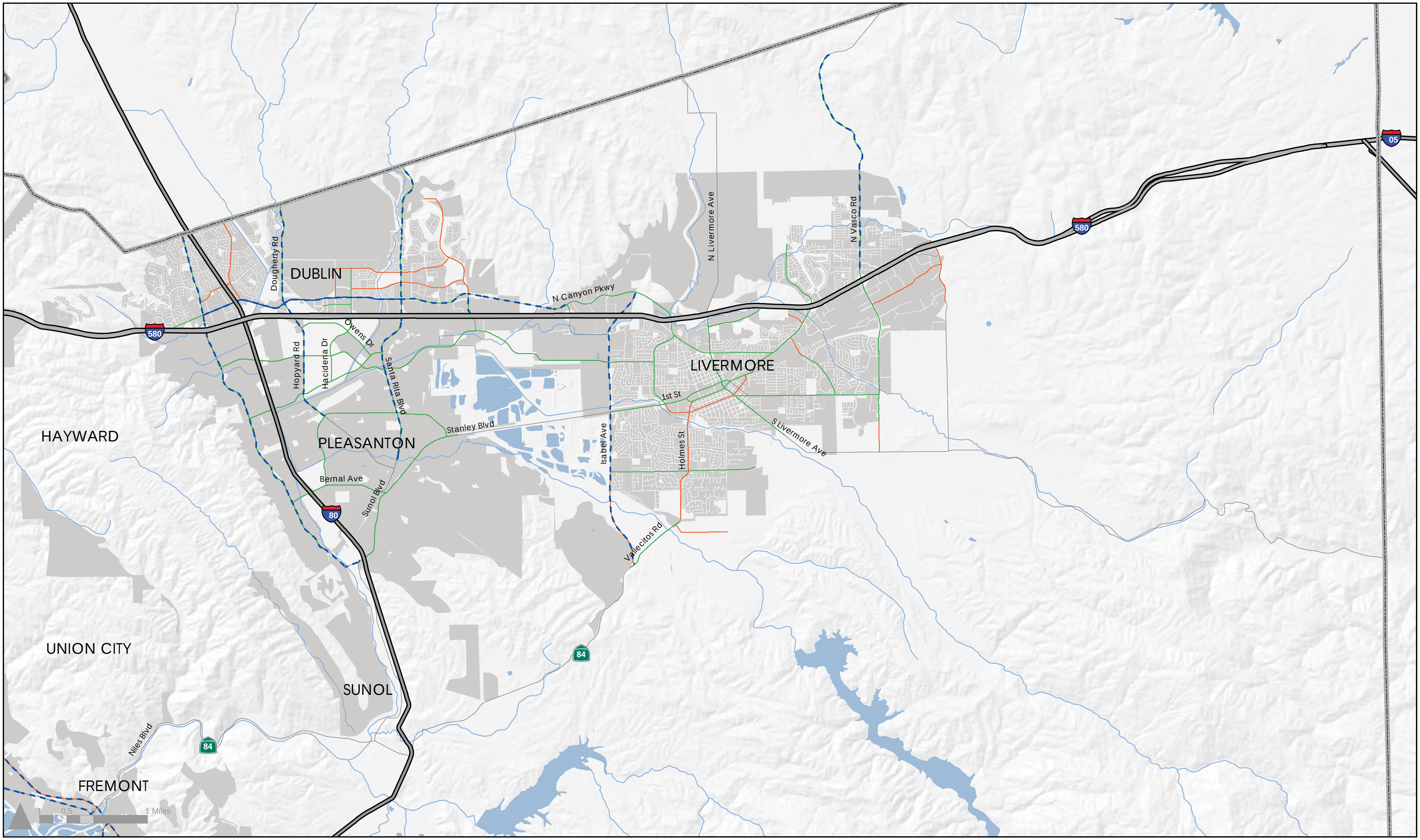
ALAMEDA County Transportation Commission

Alameda Countywide Multimodal Arterial Plan

South County

Figure 4

ITS Network Proposed Improvements



Legend

- Baseline High Level of ITS Infrastructure
- Baseline Medium Level of ITS Infrastructure
- Baseline Low Level of ITS Infrastructure
- Proposed High Level of ITS Infrastructure
- Proposed Medium Level of ITS Infrastructure
- Proposed Low Level of ITS Infrastructure
- Urban Area

Alameda Countywide Multimodal Arterial Plan

East County

Figure 5

ITS Network Proposed Improvements

ATTACHMENT A | Non-Performing Roadway Segments (Transit)

	Corridor	Routes Served	Existing	Planned/ Funded ITS Level (Year 2020)	Proposed ITS Improvements (Year 2040)	Notes
1	Adeline/40th St. (Emeryville, Oakland, Berkeley)	F	1	1	2	TSP, CCTV and upgraded Field-to-Center communications are needed. AC Transit has identified this corridor as a BRT candidate by 2040.
2	College Ave./University Ave. (Alameda, Oakland, Berkeley)	51A, 51B	1	2	3	TSP is planned for Route 51. Recommend real-time bus arrival information be provided at the stops and via the internet. AC Transit has identified this corridor as a BRT candidate by 2040.
3	East 14th St./Mission Blvd. (San Leandro, Hayward, Union City, Fremont)	99	1	1	3	Route 99 was considered to receive adaptive traffic control and TSP as part of the Transit Performance Initiative/NextGen AOP program. The project did not proceed due to funding constraints. Recommend going forward with adaptive and TSP on this corridor. AC Transit has identified this corridor as a BRT candidate by 2040. Segment includes a future east-west connector, and an additional segment located south of Fremont.
4	Foothill Blvd. (Oakland, San Leandro)	40	1	1	2	Existing ITS infrastructure on this corridor in the City of Oakland is minimal. There are no communications from the Oakland TMC to the intersection. Recommend establishing communications to the intersections and deploying TSP on this corridor.
5	Fruitvale Ave. (Oakland, Alameda)	20, 21	1	1	2	Existing ITS infrastructure on this corridor is minimal. There are no communications from the Oakland TMC to the intersection and limited communications in the City of Alameda. Recommend establishing or upgrading communications to the intersections and deploying TSP on this corridor.
6	Hesperian Blvd. (San Leandro, Union City, Hayward, Alameda County)	97	1	2	3	Will receive adaptive control and TSP as part of the Transit Performance Initiative/ NextGen AOP Program. Hesperian Blvd is also a corridor that is ideal for automobile ITS improvements such as CMS/Trailblazer Signs and CCTV cameras in addition to the TSP and adaptive control currently slated for deployment in 2017.
7	International/East 14th St. (Oakland, San Leandro)	1, 1R	1	3	3	TSP is currently installed on Route 1R. This corridor is part of AC Transit's East Bay BRT Project and will receive a wide array of ITS improvements. AC Transit is considering extending the BRT corridor from San Leandro BART to Bay Fair BART by 2040.
8	MacArthur Blvd. (Oakland)	57, 58L, NL	1	1	3	Existing ITS infrastructure on this corridor is minimal. Recommend deploying Center-to-Field communications and TSP. Additionally AC Transit has identified this corridor as a BRT candidate between now and 2040.

9	San Pablo/MacDonald (Oakland, Emeryville, Berkeley, El Cerrito, Richmond)	72, 72M, 72R	2	2	3	TSP has been installed on this corridor for over a decade as part of the 72 Rapid program. In the near term (i.e. 2020) recommend the existing TSP and communications capabilities be maintained as 72 Rapid system components reach the end of their useful life. This corridor has been identified by AC Transit as a BRT candidate between 2020 and 2040. Recommend consideration be given to deploying adaptive traffic control technology on the corridor as well.
10	Shattuck Ave. (Oakland, Berkeley, Albany)	18	1	1	2	Existing ITS infrastructure is lacking in major portions of the corridor. Recommend deploying/upgrading Center-to-Field communications along the length of the corridor and deploying TSP.
11	Telegraph Ave. (Alameda, Oakland, Berkeley)	1, 1R	2	2	3	TSP is deployed on this corridor as part of the 1 Rapid program. Between now and 2020, recommend consideration be given to deploying adaptive traffic controls on this corridor. This corridor has been identified as a BRT candidate by AC Transit.
12	Dublin Blvd./Stanley Blvd (Dublin, Livermore, Pleasanton)		2	3	3	LAVTA staff have identified this corridor as critical. It will be expanded as Dublin Blvd is extended to Livermore border.

ATTACHMENT B | Non-Performing Roadway Segments (Auto)

	Arterial	Segment Limits	Existing	Planned/ Funded ITS Level (Year 2020)	Proposed ITS Improvements (Year 2040)	Notes
1	Buchanon St.	I-580 to Pierce St. (Albany)	3	3	3	This segment is included in the I-80 ICM program and will be upgraded to Level 3.
2	Gillman St.	I-80 to Santa Fe Ave. (Berkeley)	3	3	3	The portion between I-80 and San Pablo are part of I-80 ICM and have communications to all signals as well as trailblazer signs between I-80 and San Pablo Avenue. This portion is considered Level 3 however the other half of the segment does not have any I-80 ICM upgrades. Recommend no ITS investment on the segment between San Pablo Ave and Santa Fe Ave since it is a residential street. As an aside, most of the local agencies on the I-80 ICM project are receiving upgraded central traffic control systems to support the signals in the I-80 ICM project area. This is replacing the existing McCain system that is rapidly becoming obsolete. Iteris recommends each city migrate all of their signals to the new system.
3	SR 13	Telegraph Ave. to SR24 (Berkeley)	1	1	2	Road changes name from Ashby to Tunnel Road at Claremont Ave. Recommend establishing filling any communication gaps, perform regular signal timing that is coordinated with the City of Berkeley as this is a state route that winds through the City. Also deploy CCTV cameras to monitor operations.
4	Constitution Way	Webster St. to Marina Village Parkway (Alameda)	Not Available	1	3	Recommend filling communications gaps, regular traffic signal timing, deployment of CCTV cameras, and deployment of CMS/Trailblazer signs to alert motorists of congestion in the tunnel prior to decision points.
5	Harrison St.	Grand Ave. to Fairmount Ave. (Oakland)	0	0	2	Recommend combining segments 6 through 9 into a single corridor. A lot of commuters travel from downtown Oakland to I-580 on Harrison Street. Recommend filling communications gaps, regular traffic signal timing and deployment of CCTV cameras.
6	Oakland Ave.	Perry Place to Santa Clara Ave. (Oakland)	0	0	2	I-580 Harrison Street on-ramp/off-ramp. Recommend filling communications gaps, regular traffic signal timing and deployment of CCTV cameras.
7	Harrison Street	Stanley Place to Santa Clara Ave. (Oakland)	0	0	2	I-580 Harrison Street on-ramp/off-ramp. Recommend filling communications gaps, regular traffic signal timing and deployment of CCTV cameras.
8	Oakland Ave.	Bayo Vista Ave. to Olive Ave. (Oakland/Piedmont)	0	0	3	Just east of 580/Harrison Street ramps. Recommend filling communications gaps, regular traffic signal timing and deployment of CCTV cameras.
9	Oakland Ave.	Sunnyside Ave. to Highland Ave. (Piedmont)	0	0	3	Just east of 580/Harrison Street ramps. Recommend filling communications gaps, regular traffic signal timing and deployment of CCTV cameras.

10	Doolittle Dr.	Fernside Ave. (Alameda) to Davis St. (Oakland)	Not Available	1	3	Recommend combining the next two segments with this into a single airport area project. Recommend establishing communications to all traffic signals, regular traffic signal timing to include special timing for holiday travel period, deployment CCTV cameras for monitoring and deployment of additional CMS units to display airport area travel information. The signs would present information that is similar to what is broadcast on the HAR. Recommend evaluating the future utility of HAR.
11	Airport Access Rd/Bessie Coleman Dr.	Hegenberger Rd. to OAK Arrival/Departure (Oakland)	1	1	3	See recommendations for Doolittle Drive.
12	Davis Street	Doolittle Dr. to East 14th St. (San Leandro)	2	2	3	See recommendations for Doolittle Drive. San Leandro staff recommended extending the segment over the freeway.
13	East 14th Ave.	Plaza Dr. to Elgin St. (San Leandro)	0	1	2	AC Transit has identified extending their BRT project from the San Leandro BART station to the Bay Fair BART station before 2040. This corridor would be adjacent to the extended BRT project. If this segment is extended another few blocks to Lewelling Blvd, then it would link to another underperforming corridor. Recommend filling any communications gaps, traffic signal timing at regular intervals
14	Lewelling Blvd.	Hesperian Blvd. to Mission Blvd. (San Lorenzo)	0	1	3	Reliever route for traffic on I-238 between I-580 and I-880. This segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status. Recommend filling communications gaps, regular traffic signal timing, CCTV cameras, and consideration given to adaptive traffic control. Recommend deployment to CMS/Trailblazer signs to provide traveler information.
15	Hesperian Blvd.	Lewelling Blvd. to Tennyson Rd. (Hayward)	1	3	3	This segment is part of the MTC NextGen AOP and will receive adaptive traffic control by 2017. In addition, this segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status. Recommend combining with Lewelling Blvd. and applying the same strategies.
16	A St.	Foothill Blvd. to Grove Way (Hayward)	0	1	2	Segment is on the route from downtown Hayward to I-580. Recommend filling any communications gaps, traffic signal timing and CCTV cameras for monitoring.
17	Winton Ave.	D St. to Jackson St. (SR 92) (Hayward)	1	1	2	Jackson St is SR92 in the City of Hayward. Recommend filling any communications gaps, traffic signal timing and CCTV cameras for monitoring.
18	Jackson St.	Meek Ave. to Santa Clara St. (Hayward)	1	1	3	Combine with Winton Ave from D Street to Jackson St segment. Recommend traffic signal timing and CCTV cameras for monitoring.
19	Mission Blvd.	Jackson St. to Whipple (Hayward)	1	3	3	This portion of Mission Blvd was transferred from Caltrans to Hayward. Hayward has already upgraded the communications and deployed adaptive control (SCATS) on this segment. Recommend consideration be given to additional CCTV cameras and CMS/Trailblazer signs in the long term.
20	Mission Blvd.	Decoto Rd. to I-680 (Hayward to Fremont)	1	1	3	Recommend filling any communications gaps, traffic signal timing and CCTV cameras for monitoring. Recommend consideration of adaptive traffic control and additional CMS/Trailblazer signs.

21	Industrial Blvd./Industrial Pkwy.	Clawiter Rd. to I-880 (Hayward)	0	1	3	Cut-through for traffic going between I-880 and SR92 (San Mateo Bridge). This segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status. Recommend filling any communications gaps, traffic signal timing and CCTV cameras for monitoring. Hayward staff recommend extending the segment beyond SR92 to Clawiter Road to close a gap in the ITS infrastrucuture.
22	Industrial Pkwy.	Russ Rd. to Huntwood Ave. (Hayward)	0	1	3	Could be combined with Industrial segment between Arden and I-880. This segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status. Recommend filling any communications gaps, traffic signal timing and CCTV cameras for monitoring.
23	Whipple Rd.	Dyer St. to Industrial Pkwy SW (Hayward)	1	1	3	I-880/Whipple interchange. This segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status.
24	Industrial Pkwy SW	Whipple Rd. to Industrial Pkwy W	0	1	3	This segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status.
25	Alvarado Niles Rd./Smith St.	Union City Blvd to Osprey Drive (Union City)	1	1	3	This segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status.
26	Mowry Ave.	Mission Blvd. to Peralta Blvd. (Fremont)	0	1	3	This segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status.
27	Osgood Rd.	Washington Blvd. to Grimmer Blvd. (Fremont)	2	2	3	Parallels I-680 near Washington and Auto Mall on-ramps. A lot of retail is off of Auto Mall between I-880 and I-680. A new BART station is opening nearby. Recommend filling any communications gaps, traffic signal timing and CCTV cameras for monitoring. In addition, consider installation of CMS/Trailblazer units for incident management.
28	Mission Blvd.	I-680 to I-880 (Fremont)	1	1	3	Huge commuter route with lots of retail. This segment is part of the I-880 ICM program and will receive an upgrade to Level 3 status.
29	Isabel Road (SR84)	Vallecitos Road (SR84) to Concannon Blvd. (Livermore)	1	1	3	SR84 was rerouted to Isabel Road at Vallecitos Road with Isabel going to the State and the City taking over Vallecitos Road east of Isabel. This segment was not modernized when the road was turned over to Caltrans. Recommend filling communications gaps, traffic signal timing at regular intervals and CCTV cameras for monitoring. Consideration to be given to CMS/Trailblazer to alert motorists of incidents and alternate routes.
30	Vasco Road	I-580 to Los Vaqueros Road (Livermore/Unincorporated)	2	2	3	Vasco Road is known to have a high number of accidents. Many measures are already in place. Road is used as a commuter route for people living in the Brentwood area to Silicon Valley. Recommend additional CCTV cameras and CMS signs.
31	Foothill Rd./San Ramon Rd.	Golden Eagle Way to Contra Costa County Line (Pleasanton/Dublin)	2	2	3	Portion in Pleasanton from Stoneridge to 680 is meeting performance objectives. This is in front of Stoneridge Mall.
32	Fallon Rd./El Charro Rd.	580 to Dublin Blvd (Dublin)	2	2	3	Near Livermore Outlets and Fallon Shopping Center. Recommend extending the adaptive control system slated for installation on Dublin Blvd in 2017 through the MTC NextGen AOP to be extended along Dublin Blvd to this segment.

33	Santa Rita Rd./Tassajara Rd.	County Line (Dublin) to Del Valle Parkway (Pleasanton)	2	2	3	Recommend consideration be given to extending the adaptive control system slated for installation on Dublin Blvd in 2017 through the MTC NextGen AOP.
34	Hopyard Rd./Dougherty Rd.	Valley Ave. (Pleasanton) to Contra Costa County Line (Dublin)	2	2	3	Recommend extending the adaptive control system slated for installation on Dublin Blvd in 2017 through the MTC NextGen AOP to be extended along Dublin Blvd to this segment.
35	DeCoto Rd.	Mission Blvd to Paseo Padre Pkwy (Union City)	1	1	3	Union City staff have identified this corridor as critical.
36	Dyer St	Whipple Rd. to Union City Blvd. (Union City)	1	1	3	Union City staff have identified this corridor as critical.
37	Union City Blvd.	Whipple Rd. to Paseo Parkway (Union City)	1	1	3	Union City staff have identified this corridor as critical.
38	Alvarado Blvd.	Union City Blvd. to Galaxy Dr. (Union City)	1	1	3	Union City staff have identified this corridor as critical.
39	Dublin Blvd.	San Ramon Road to Tassajara Rd. (Dublin)	2	3	3	MTC's Next Generation Arterial Operations Program will install adaptive control in 2017 to go along with existing TSP. Adaptive will be deployed from San Ramon Road to Hacienda Drive. Recommend extending adaptive to the entire arterial. Currently that would be Tassajara Road. If Dublin Blvd. is ever extended to the Livermore City Limit, then recommend expanding the adaptive system as well. This corriedor serves as a freeway reliever route. In the long term deploying V2I infrastructure is recommended.
40	Tennyson Rd	East of I-880 to Industrial Blvd. (Hayward)	0	0	3	Hayward staff recommend deploying mid-level ITS measures. Currently there is nothing in place.
41	Foothill Blvd	Mission Blvd to I-580 (Hayward)	0/1	0	3	Hayward staff recommend deploying high-level ITS measures.
42	Second St.	A St. to E St. (Hayward)	1	1	1	Hayward staff recommend deploying low level ITS measures.
43	B St.	Foothill Blvd to 4th St (Hayward)	0	0	2	Hayward staff recommend deploying medium level ITS measures.
44	A St.	Meekland Ave and I-880 (Hayward)	0	1	2	Hayward staff recommend deploying medium level ITS measures.
45	Hesperian Blvd.	East 14th St and Thornally Drive (San Leandro)	2	2	3	San Leandro staff recommend deploying high level ITS.
46	Park Street	Santa Clara Avenue to Park Street Bridge (Alameda)	Not Available	0	3	Alameda staff recommend deploying high level ITS on this segment.
47	Shattuck Ave	Durant Ave. to Adeline St. (Berkeley)	0	0	3	Berkeley staff recommend deploying high level ITS including TSP and adaptive traffic control to support future dedicated bus ROW and transit queue jumps potentially.
48	Shattuck Ave.	Hearst St. to Rose St. (Berkeley)	0	0	3	Berkeley staff recommend deploying high level ITS including TSP and adaptive traffic control to support future dedicated bus ROW and transit queue jumps potentially.

49	Adeline St	Ward St to 62nd St (Berkeley)	0	0	3	Berkeley staff recommend deploying high level ITS including TSP and adaptive traffic control to support future dedicated bus ROW and transit queue jumps potentially.
50	Sacramento St	Alcatraz Ave to Cedar St (Berkeley)	0	0	2	Berkeley staff recommend deploying medium level ITS on this segment.to include TSP and adaptive traffic control.
51	MLK Jr. Way	Hopkins St to Adeline St. (Berkeley)	0	0	2	Berkeley staff recommend deploying medium level ITS on this segment.to include TSP and adaptive traffic control.
52	Shattuck Ave.	Woolsey St to Adeline St. (Berkeley)	0	0	2	Berkeley staff recommend deploying medium level ITS on this segment.to include TSP and adaptive traffic control.
53	College Ave.	Broadway to Bancroft Ave. (Berkeley)	0	0	2	Berkeley staff recommend deploying medium level ITS on this segment.to include TSP and adaptive traffic control.
54	Dwight Way	7th St and Warring St. (Berkeley)	0	0	2	Berkeley staff recommend deploying medium level ITS on this segment.to include TSP and adaptive traffic control.
55	Ashby Ave.	Adeline St and Telegraph Ave. (Berkeley)	0	0	2	Berkeley staff recommend deploying medium level ITS on this segment.to include TSP and adaptive traffic control.