Concept Exploration for Integrated Corridor Management

FINAL

CONTRA COSTA
transportation
authority

Innovate 680

Concept Exploration for Integrated Corridor Management

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Contra Costa Transportation Authority

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Abbreviations

ATM	Active Traffic Management
ATMS	Advanced Traffic Management Systems
AV	Autonomous Vehicle
BOS	Bus on Shoulder
CCTA	Contra Costa Transportation Authority
C-D	Collector-Distributor
ConOps	Concept of Operations
CV	Connected Vehicle
DMS	Dynamic Message Sign
DSRC	Dedicated Short Range Communication
FM/LM	First Mile/Last Mile
HOV	High Occupancy Vehicle
IOS	Innovative Operational Strategies
ITS	Intelligent Transportation Systems
MTC	Metropolitan Transportation Commission
SAV	Shared Autonomous Vehicle
SOV	Single Occupancy Vehicle
TDM	Transportation Demand Management
TOS	Traffic Operations System
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle

Glossary

Concept	A high-level conceptual project description, including services provided and the operational structure
Concept of operations	A document that defines the way the system is envisioned to work from multiple stakeholder/user viewpoints.
Concept exploration	The process of developing and comparing alternative conceptual approaches to meeting the needs that drive the project.
Evaluation	The process of determining whether an item or activity meets specified criteria.
Evolutionary development	Breaking a project down into parts and developing them in a serial fashion.
Feasibility assessment	A pre-development activity to evaluate system concepts, select the best one, and verify that it is feasible within all the projects and system constraints.
Gap analysis	A technique to assess how far current (legacy) capabilities are from meeting the identified needs, to be used to prioritize development activities.
Intelligent transportation systems	A broad range of diverse technologies which, when applied to our current transportation system, can help improve safety, reduce congestion, enhance mobility, minimize environmental impacts, save energy, and promote economic productivity. ITS technologies are varied and include information processing, communications, control, and electronics.
Life cycle	The end-to-end process from conception of a system to its retirement or disposal.
Metrics	Measures used to indicate progress or achievement.
Needs assessment	An activity accomplished early in system development to ensure that the system will meet the most important needs of the project's stakeholders, specifically that the needs are well understood, de-conflicted and prioritized.

Operational concept	The roles and responsibilities of the primary stakeholders and the systems they operate.
Performance	A quantitative measure characterizing a physical or functional attribute relating to the execution of a mission/operation or function.
Project	An undertaking requiring concerted effort, which is focused on developing and/or maintaining a specific product. The product may include hardware, software, and other components.
Requirements	The total consideration as to what is to be done (functional), how well it should perform, and under what conditions it is to operate.
Stakeholders	The people for whom the system is being built, as well as anyone who will manage, develop, operate, maintain, use, benefit from, or otherwise be affected by the system.
System	An integrated composite of people, products, and process, which provide a capability to satisfy a stated need or objective.
Systems engineering	An inter-disciplinary approach and a means to enable the realization of successful systems.
System specification	A top-level set of requirements for a system.
User	The organization(s) or persons within those organizations who will operate and/or use the system for its intended purpose.
Validation	The process of determining that the requirements are the correct requirements and that they form a complete set of requirements. Validation of the end product or system determines if the system meets the user needs.

1. PURPOSE OF THE CONCEPT EXPLORATION DOCUMENT

This report describes a series of innovative improvements to the I-680 Corridor that will turn the tide of escalating congestion and delays by using all the best emerging technologies that collectively lead to smart mobility. These improvements will be designed, built, integrated, and operated in a coordinated fashion. The feasibility, cost and benefit of each improvement is addressed in this report. Together, these improvements are being called the "Innovate 680" program.

The I-680 transportation corridor, consisting primarily of the highway and the BART Yellow Line, provides the most convenient northbound and southbound mobility in Contra Costa County for many travelers including commuters and residents. With increasing population growth and development, convenience becomes a liability, as the corridor attracts daily demand well beyond its capacity. Although the majestic Mount Diablo once towered over a river of fluid vehicular mobility, it now looks down through the haze of smog at a creeping mass of viscous automotive sludge that unchecked will surely earn it the moniker of "The Devil's Freeway." The map provided in Figure 1 shows the key transportation features of the I-680 Corridor.

FROM THE CALTRANS SYSTEMS ENGINEERING GUIDELINES:

"Concept Exploration is used to perform an initial feasibility & benefits analysis and needs assessment for the candidate projects from the regional ITS architecture. This results in a business case and specific cost benefit analyses for alternative project concepts. The output of this stage is a definition of the problem space, key technical metrics, and refinements to the needs, goals, objectives, and vision. This stage identifies the highest cost/benefit concept [best business case] project to move forward into development."

1.1 QUESTIONS AND ANSWERS ABOUT THE CONCEPT EXPLORATION REPORT

What is the purpose of the Concept Exploration Report?

This report describes a conceptual approach to a series of interrelated improvement projects included in the Innovate 680 program. It describes the need for operational improvements and provides a vision and mission for the overall program. It identifies the key institutional and public stakeholders who are participating to help shape the program. These stakeholders have provided the Contra Costa County Transportation Authority (CCTA) with input during a series of meetings held between October 2016 and the present. The Concept Exploration Report describes how the planned improvements fit into an industry standard approach called Integrated Corridor Management (ICM), defined herein. It documents the development of ICM alternatives to a level of completion sufficient to facilitate comparison and assessment of alternative approaches based on estimated costs and projected benefits.

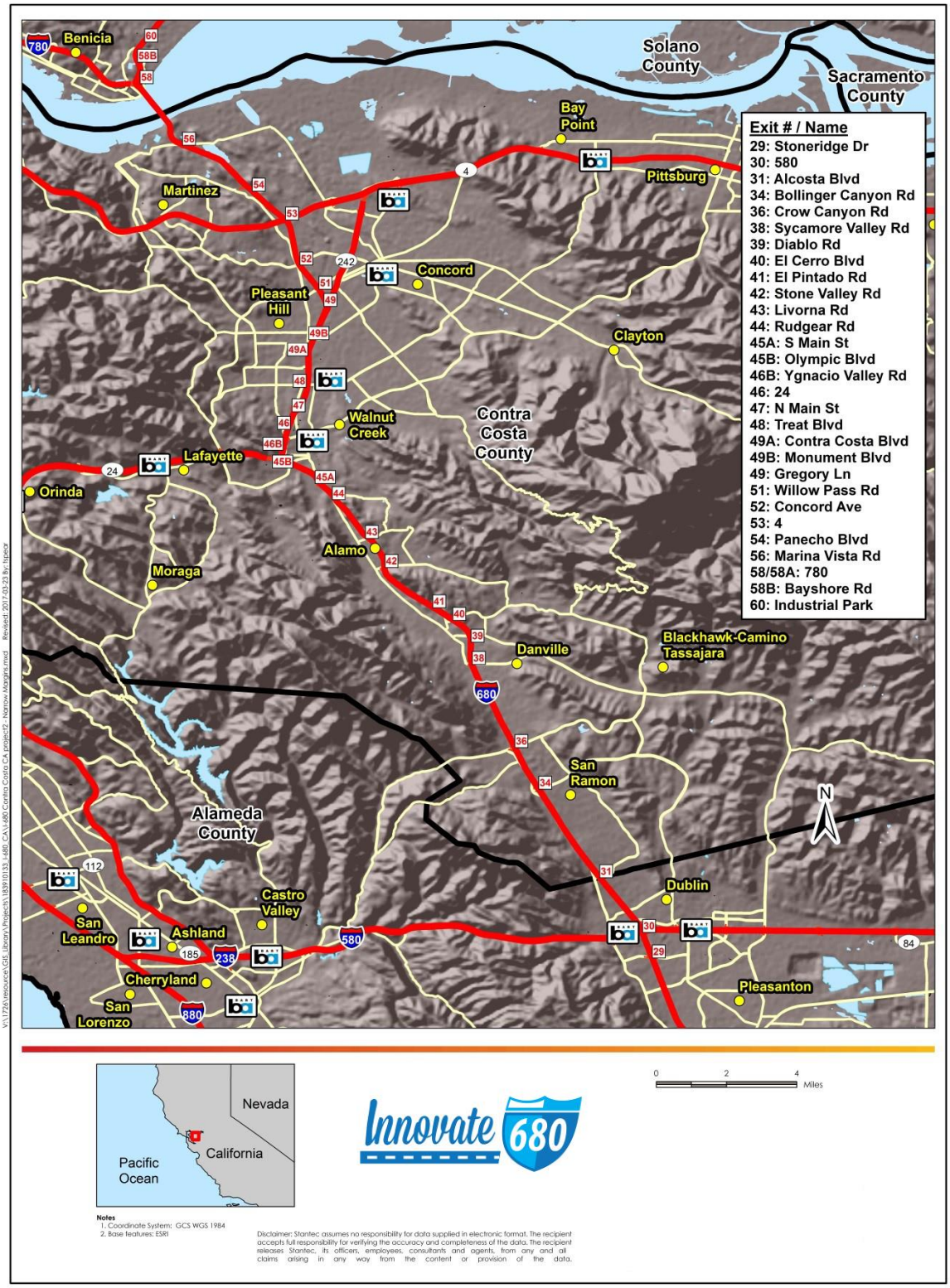

Figure 1: The I-680 Transportation Corridor in Contra Costa County

What is a "Concept Exploration" report, and how does it fit in the project development process? How does it differ from a "Concept of Operations?"

Concept Exploration is an abbreviated name for "Concept Exploration and Benefits Analysis Roadmap" as defined by the Caltrans Systems Engineering Guidelines[1] as "Phase 0" of the systems engineering process. This does not replace the Concept of Operations in the project development process. In the case of the "Innovate 680" program of projects, the Concept Exploration document is a precursor report to a formal Concept of Operations expected to be developed at a later time. It differs from the Concept of Operations or "ConOps" by covering only part of the outline for a standard Caltrans ConOps. This is necessary to create alternative approaches for consideration, and document potential costs and benefits, before selecting a solution to progress into the Concept of Operations phase.

Why is a "Concept Exploration" report being done for Innovate 680 instead of a full Concept of Operations?

The Concept Exploration is being done for Innovate 680 to evaluate a collection of proposed Corridor improvements in terms of probable costs and anticipated benefits. This is necessary to formulate a strategic approach to implement a series of projects that will deliver the highest value and address the needs of the Corridor most effectively. This document incorporates the "Seven Strategies[2]" developed by the CCTA to address operational needs of the I-680 Corridor. The Seven Strategies White Paper was developed with collaboration from the Metropolitan Transportation Commission and Caltrans District 4 at a series of meetings in the Fall of 2016, and subsequent review and comment on the white paper. It can be thought of as a way of separating the ConOps into two parts, the first part evaluating all available options, and then the second part identifying the system solution needed to deliver the desirable options. This report provides the foundation for a future comprehensive ***Concept of Operations*** for Integrated Corridor Management (ICM) of Interstate 680 in Contra Costa County.

What is "Innovate 680?" How is it different than what CCTA has always done?

"***Innovate 680***" is envisioned to be a program consisting of a series of innovative operational improvements that have a relatively low cost of implementation compared to major highway construction. It brings to bear emerging technologies such as Connected Automated Vehicles (CAV) to improve safety and reduce crash delays. Planning and progressing a series of transportation improvements is nothing new, it is what CCTA has done throughout its history. The difference between this new approach and past practices is that although the improvements may be implemented as separate projects, CCTA is investigating the added benefit of operating the improvements as a single system for advanced mobility. All of the improvements included in Innovate 680 will be part of an integrated operational environment. This approach is designed to avoid the all too common occurrence of fixing a problem in one place only to shift the problem downstream or upstream to another place. Today's climate of patchwork transportation funding from small "pots" of money and dedicated grant programs that have a

[1] Systems Engineering Guidebook for Intelligent Transportation Systems Version 3.0, November 2009, Caltrans and the USDOT Federal Highway Administration California Division, http://fhwa.dot.gov/cadiv/segb

[2] Innovate 680 Seven Strategies, White Paper, February 8, 2017, Contra Costa Transportation Authority.

limited scope or required solution invite disconnected operations. Innovate 680 will tie each and every improvement into the overarching integrated goals of safety and enhanced mobility.

What is contained in the Concept Exploration Report and how is it organized?

This report contains six chapters. Each Chapter has been prepared with conformity to the descriptions related to Concept Exploration Phase in the Caltrans Systems Engineering Guidelines.

- Chapter 1 *PURPOSE OF THE CONCEPT EXPLORATION DOCUMENT* describes the purpose and relevance of the Concept Exploration, and introduces the Innovate 680 program.
- Chapter 2 *HIGH LEVEL DESCRIPTION* is a description of the scope of the program and provides the vision and mission of the systems to be developed. It includes insights into the expected operations of the system under development. Key institutional stakeholders are identified and their roles described.
- Chapter 3 *BACKGROUND:* EXISTING *CONDITIONS AND NEEDS* is a description of the current mobility conditions in the I-680 Corridor and the capabilities of the legacy Intelligent Transportation Systems. The existing operation is described along with gaps, drawbacks, and limitations. This Chapter clarifies the need for change and states the reasons for the proposed improvements.
- Chapter 4 *COMPONENT STRATEGIES* provides a more detailed description of the component strategies that were selected as part of the Innovate 680 Program. Of the many improvements described, the ones that will contribute to the real-time day to day Integrated Corridor Management (ICM) approach (e.g. Adaptive Ramp Metering, Bus on Shoulder Operations, Traffic Operations Systems) are identified.
- Chapter 5 *CONCEPT EXPLORATION* describes how the real time operational improvements identified in Chapter 4 will be woven into the "system of systems" ICM solution. The technologies to be deployed to implement the component strategies are described as subsystems. This is followed by a discussion of the nature of the planned changes and a justification for them.
- Chapter 6 *COST AND BENEFITS OF DEPLOYMENT ALTERNATIVES* identifies benefit/cost ratios from the research literature for the ICM subsystems described in Chapter 5. Three alternative approaches to deployment of the ICM are provided. The three approaches are compared with respect to the anticipated benefits and costs anticipated over time. A strategic deployment plan is recommended and an investment strategy is proposed.
- Chapter 7 *IMPLEMENTATION PLANNING* presents the approach to deployment of the seven Innovate 680 strategies in the form of executable projects.

The Concept Exploration Report was circulated in draft form to the key institutional stakeholders for review and comment, and this final version is being published and made available to all interested parties. The Report will also be presented to the CCTA Board of Directors to facilitate discussion of the recommended alternative.

2. HIGH LEVEL DESCRIPTION

The Innovate 680 Program will develop and implement an Integrated Corridor Management (ICM) System to provide an integrated, coordinated operation of the transportation management assets in the Corridor. Figure 2 lists the major systems that provide real-time operational mobility in the Corridor. The coordination of these subsystems will allow for the mitigation and management of growing congestion on I-680.

The Innovate 680 program of projects combines past improvements already operational with improvements currently underway and future improvements to the highway into a new ICM system. This system will include proximate transportation assets like parking garages at the transit stations and express bus operations. The program includes civil infrastructure improvements and operational improvements. Every capital improvement programmed will also require electronic computer based systems to manage operational elements. An example of this "instrumentation" of the infrastructure is the addition of Express Lanes in the median of the highway. Express lanes are made of concrete, steel, and asphalt. However, to *operate* Express Lanes, the civil infrastructure must be instrumented with electronic tolling systems, traffic operations systems and vehicle detection. Capital investment is required for civil construction, traffic engineering features such as signs and pavement markings, and electronic elements consisting of Intelligent Transportation Systems (ITS) devices.

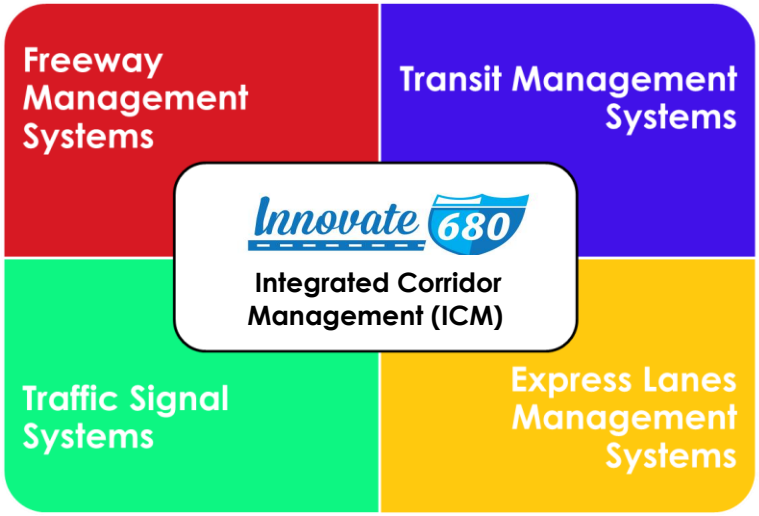

Figure 2: High Level Organization of I-680 Management Systems

2.1 VISION AND MISSION

The increase in congestion on I-680 in Contra Costa County is noted by all, including political officials, elected representatives, travelers, and residents. To allow the congestion to get worse would be to invite a vision of increased pollution, erosion of property value, more vehicle crashes and lost productivity. The Vision of the Innovate 680 program is a highway Corridor where the rate of increase of congestion reverses and optimal operational objectives are achieved on a regular basis. This includes a reduction in crashes, longer periods of non-congested operations every day, and better utilization of the transit services offered.

To build stakeholder support for the Innovate 680 program, a unifying vision and mission statement were developed and adopted. Developing a vision is part of the Systems Engineering

process. It answers the question of "what will this system look like to be successful?" A mission statement is more action oriented, and answers the question "what do we need to do to achieve the vision?"

2.1.1 The Innovate 680 Goals and Objectives

To create a vision of what the system will look like, the operational goals and objectives need to be considered. The goal of the Innovate 680 program is to increase the throughput of people and vehicles in the I-680 Corridor by leveraging all transportation assets and optimizing their use through the deployment of integrated corridor management strategies that will enhance mobility, safety, the environment, and provide a Corridor that is resilient and can meet socio-economic growth demands for today and the future. The program objectives include the following:

- Encourage and foster innovation
- Improve mobility/congestion reduction
- Improve safety
- Increase transit ridership
- Bolster access to transit
- Increase car/van pooling
- Stabilize system reliability
- Promote environmental sustainability
- Provide a foundation for future operation of connected and autonomous vehicles
- Improve Incident Management
- Improve traveler information

2.1.2 The Innovate 680 Mission

The mission for the Innovate 680 program was created by a collaborative process with the key institutional stakeholders. The mission answers the question "What is it that the stakeholders want to do?" The following "mission elements" were developed with key institutional stakeholder input:

- Incorporate innovative new techniques and strategies represented in the seven Innovate 680 components
- Deploy the latest emerging transportation technologies, in some cases for the first time
- Provide and enhance alternative travel modes
- Promote sustainable solutions, rather than infrastructure mega-projects that consolidate available funding to one segment to the detriment of global corridor needs
- Manage improvements in the Corridor to compliment a coordinated strategy
- Provide more efficient transportation services that reduce wasted time and energy

- Invest in modern and innovative transportation assets that are:
  - Safe
  - Reliable
  - Accessible
  - Sustainable
- Optimize the use of existing infrastructure and operational assets
- Leverage underutilized capacity along the entire I-680 transportation and mobility Corridor
- Prepare the Corridor for the future including connected and autonomous vehicles
- Create a "system of systems" to meter ramps, optimize traffic signals, increase transit ridership and fully utilize transit parking facilities
- Modernize the Corridor to today's Intelligent Transportation Systems (ITS) standards

2.1.3 The Innovate 680 Vision Statement

The vision was created by a collaborative process with the Innovate 680 institutional stakeholders.

The Innovate 680 program will include the development of a new Integrated Corridor Management (ICM) System that will be a "system of systems" that manages all the Corridor transportation assets to provide safe, reliable, and efficient mobility for all system users. The ICM system will establish and maintain non-congested highway operations, respond to events that tend to introduce congestion and more fully utilize all available public transportation assets including trains, buses, and parking spaces. All available and proven ITS technologies will be deployed, integrated into the ICM System, and leveraged to measure, adjust, and maximize mobility. Key Performance Indicators (KPI) will be established and used by the system to measure performance and improve operations over time.

The Innovate 680 program will include the development of a new Integrated Corridor Management (ICM) System that will be a "system of systems" that manages all of the corridor transportation assets to provide safe, reliable and efficient mobility for all system users.

Figure 2 lists the elements necessary to build the envisioned ICM system. Each of the subsystems depicted in Figure 2 will be more fully described in Chapter 4 of this report.

2.2 KEY INSTITUTIONAL STAKEHOLDERS

Implementing the Innovate 680 program requires collaboration from the key institutional stakeholder responsible for the Corridor. There are numerous institutional stakeholders, including local, state and federal agencies which play key roles in the operation and management of the I-680 Corridor. Contra Costa Transportation Authority (CCTA) has taken the lead to identify and organize the key stakeholders along the Corridor for the purpose of the Innovate 680 program. Key Stakeholders are the subset of all stakeholders responsible for the planning stages of a major transportation improvement program. CCTA will perform planning and oversight of individual projects in order to control progress toward achieving the goals and objectives to realize the program vision. The following sections summarize each stakeholder's role in the Innovate 680 program.

2.2.1 Contra Costa Transportation Authority (CCTA)

The Contra Costa Transportation Authority (CCTA) is a public agency formed by Contra Costa voters in 1988 to manage the county's transportation sales tax program and perform countywide transportation planning. CCTA is responsible for maintaining and improving the county's transportation system by planning, funding, and delivering critical transportation infrastructure projects and programs that connect our communities, foster a strong economy, increase sustainability, and safely and efficiently get people where they need to go. CCTA is also the county's designated Congestion Management Agency (CMA), responsible for putting programs in place to keep traffic levels manageable.

2.2.2 California Department of Transportation (Caltrans)

Caltrans District 4 is the agency that currently operates the I-680 freeway from their Regional Traffic Management Center (RTMC) in Oakland. Caltrans also manages the design, construction and testing of capital and operational transportation improvements in the Corridor. Caltrans has deployed a complement of basic Intelligent Transportation Systems (ITS) components that they call Traffic Operations Systems (TOS). This includes traffic monitoring cameras, vehicle detectors, and changeable (dynamic) message signs.

Caltrans has a statewide awareness and emphasis on moving toward Integrated Corridor Management (ICM) systems in California's most congested freeway corridors.

2.2.3 Metropolitan Transportation Commission (MTC)

The San Francisco Bay Area's Metropolitan Transportation Commissions (MTC) is the lead transportation and land use planning agency planning for the nine most populous counties that constitute the Bay Area metropolitan region. The MTC is also the "banker" for the Bay Area, taking responsibility for the strategic appropriation of funding for projects and programs with a robust public involvement outreach capability. MTC's role in the Innovate 680 program is to establish consistency with MTC's regional goals, and provide access to funding mechanisms for worthy project elements. More than a planning partner, MTC has an operational role in providing the 511 Traveler Information Systems.

MTC also participates in the implementation of ICM technology, including freeway management systems for traveler information, roadway fiber optic networks, incident management, ramp metering, park & ride facilities, and HOV/Express lanes.

2.2.4 Bay Area Rapid Transit (BART)

BART is a world class regional transit service. Over 60% of BART trips are work commutes, with an even higher percentage in Contra Costa County. Without BART, I-680 congestion would gridlock the County. BART also owns and operates parking garages at the Contra Costa County BART stations. These lots tend to be full by 7:00 am on commuter work days. The limitations on parking decrease the effectiveness of the system, and many commuters who would use BART after 7 am do not do so due to the lack of parking. BART has been operating the Yellow line that connects San Francisco and Oakland to the Pittsburg/Bay Point in northern Contra Costa County since 1996. During the Concept of Operations phase, meetings will be held to better understand BART's assets and needs.

2.2.5 Contra Costa County Cities and Municipalities

The municipal street grid that operates on the flanks and across the I-680 freeway are a key part of the I-680 Corridor. These agencies are a key part of the constituency of users of transportation services in the Corridor. In the ICM deployment, the traffic signal systems operated by these agencies will be a critical key to success of the program.

2.2.6 County Connection (Central Contra Costa Transit Authority)

County Connection is currently providing public transit to the cities along I-680 Corridor. They have over 120 buses and over 60 paratransit vehicles that operate during peak commuter travel periods.

2.2.7 California Highway Patrol (CHP)

The CHP will play an important role in many aspects of the ICM, from their presence in the Caltrans TMC to their presence out on the highway. The ICM will provide the CHP with valuable information to enhance their operations. CHP will continue to provide the essential resources for incident management and participate in planning and monitoring of any new Bus on Shoulder (BOS) operations. During the Concept of Operations phase, meetings will be held to better understand CHP's assets and needs.

3 BACKGROUND: EXISTING CONDITIONS AND NEEDS

The I-680 is the only north/south freeway serving a population of over 1 million people in Contra Costa County. The I-680 Transportation Corridor is the key to mobility in Contra Costa County and its neighbors.

3.1 CORRIDOR DESCRIPTION

The project will cover the I-680 Corridor from the Alameda County line on the south to the Benicia-Martinez Bridge on the north. There are three major east west freeways that intersect with I-680 and impact traffic in Contra Costa County. Although Interstate 580 is in Alameda County, its effects are felt dramatically in Contra Costa. Figure 1 in Chapter 1 of this report is a map of the Transportation Corridor where this can be seen more clearly.

3.2 EXISTING CONDITIONS ON I-680 AND NEEDS

I-680 freeway congestion is growing worse despite investments in highway and transit infrastructure in the Corridor. Many residents were not surprised when I-680 made the MTC's list of the top 10 worst commutes in the Bay Area. The northbound p.m. peak drive from San Ramon to Treat Boulevard in Walnut Creek was the number 5 most congested location in 2013 and 2014. In more recent lists, the congestion crisis in Silicon Valley has shifted its rank because Silicon Valley has become worse, not because I-680 in Contra Costa has improved.

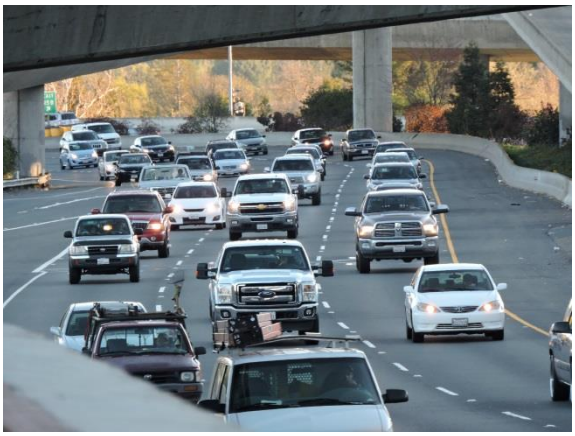

Figure 3: I-680 Typical Interchange Traffic

3.2.1 Traffic Congestion

The Innovate 680 program is one of the largest improvement undertakings in the Bay Area if measured by lane mileage. The highway segment involved is 25 miles long and the typical cross section is four lanes in either direction creating approximately 200 lane miles to be managed. The roadway does not have a typical cross section in Contra Costa County, with widely divergent structural and drainage needs over its length. In many segments, auxiliary lanes have been added. Geological, financial, and structural barriers exist that make widening the road a challenging proposition. Inconsistent right of way provisions over the 25-mile length also contribute to an inconsistent number of lanes in the Corridor. Lane drops are all too common near the interchanges. The location of the lane drops correspond with recurring congestion hot spots as daily demand grows. Hot spot congestion in the vicinity of lane drops quickly propagates upstream to segments that would otherwise not be congested. Since the lane drops that could be removed have been removed, the impacts of the existing lane drops must be

mitigated through Integrated Corridor Management ICM strategies like adaptive ramp metering. Otherwise the highway flow will continue to break down at these points in the face of unmanaged demand. Figure 4 shows the current lane balance conditions of I-680 today. The Table has been laid out to show the typical number of lanes midway between the interchanges. The red cells show a place where a lane drops in the indicated direction of travel.

Exit Number	Cross Street	SB Lane	NB Lane
56	Marina Vista		
		4	4
54	Pacheco Blvd		
		4	4
53	SR-4		
		4	4
52	Concord Avenue		
		4	4
51	Willow Pass Road		
		6	5
49	Contra Cost Blvd		
		6	6
48	Treat Blvd		
		6	5
47	N. Main Street		
		4	6
46	Ygnacio Valley Road		
		4	5
46	SR-24		
		3	3
46	Olympic		
		5	5
45	S. Main Street		
		5	4
44	Rudgear Road		
		4	4
43	Livorna Road		
		4	4
42	Stone Valley Road		
		4	4
41	El Pintado Rd		
		4	4
40	El Cerro Blvd		
		4	4
39	Diablo Road		
		4	4
38	Sycamore Valley Road		
		3	3
36	Crow Canyon Road		
		4	4
34	Bollinger Canyon Road		
		4	4

Figure 4: Lane Balance on I-680 as of March 2017

Traffic congestion analysis of the I-680 freeway tells the "tale of two highways" in that there is a significant difference in operational characteristics south of the SR-24 interchange and North of the SR-24 interchange.

Figure 5 shows the typical congestion level experienced in the northerly portion of the Corridor between SR-24 and the Benecia Bridge. This figure presents the time of day from the left to right on the horizontal axis, and the highway in the center with the cross streets identified from north at the top to south at the bottom. To the left of the center column is the southbound traffic flow, and to the right of the center column is the northbound traffic flow. The figure was generated using the on-line INRIX database. [3] The light green shading indicates average speeds for the time interval that are 50 mph or better, considered ideal conditions. Congestion starts to build between 6pm and 7pm approximately 8 miles south of the Benecia Bridge between Willow Pass Road and Monument Blvd. The dark red zone indicating total breakdown with average speeds less than 10 mph occurs between 7am and 8 am. This occurs approaching N. Main Street, and corresponds with the southbound lane drop depicted in Figure 4. Clearly adaptive ramp metering at the southbound entrance ramps north of North Main Street starting at 6 am would alleviate this issue. On the northbound side of Figure 5, the congestion in the vicinity of the I-24 interchange is severe, starting at 2 pm and continuing to 8 pm, extending as far north as Monument Blvd. It is most severe in the vicinity of North Main Street, which corresponds to the lane drop depicted in Figure 4.

[3] www.inrix.com; March 2017

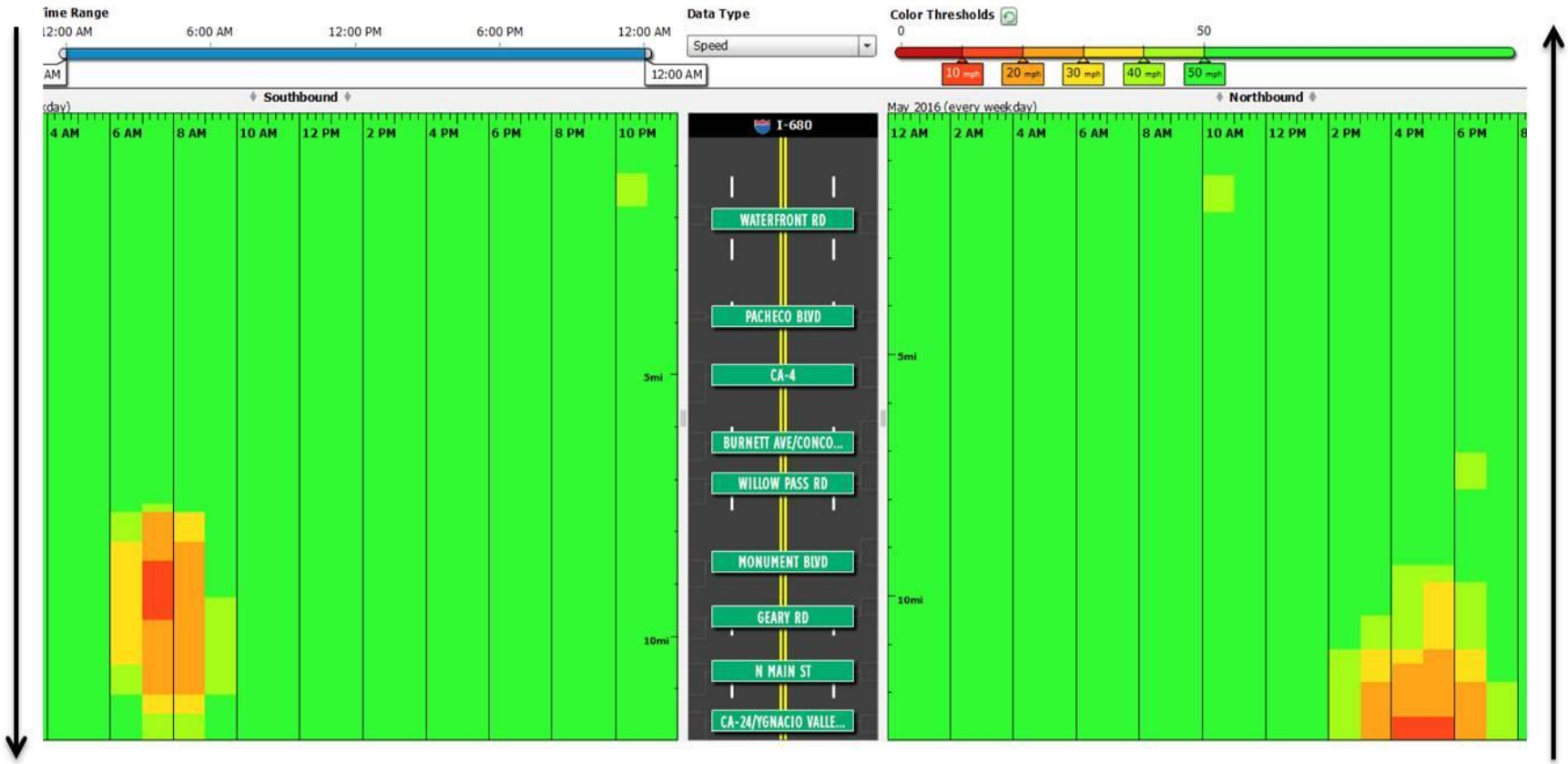

Figure 5: I-680 Congestion Profile (From SR-24 to the Benicia Bridge) May 2016 Weekdays

Figure 5 captures the massive severe congestion on I-680 on the northbound side south of North Main Street. This congestion is caused by the SR-24 eastbound to I-680 northbound movement, which consist of three lanes of heavy flow entering I-680 northbound lanes on the median side, combining with three I-680 northbound lanes from the south, and then dropping one of the six lanes down to five at the North Main Street exit ramp. Although adaptive ramp metering the northbound side of I-680 south of SR-24 could reduce the intensity of the congestion on I-680, it cannot eliminate the congestion, because I-680 is not the problem. The problem is the eastbound traffic entering I-680 northbound. There was a time when "mainline metering" would have been considered for the eastbound SR-24, however safety and public opposition would be high as this type of solution simply relocates the congestion from one freeway to another.

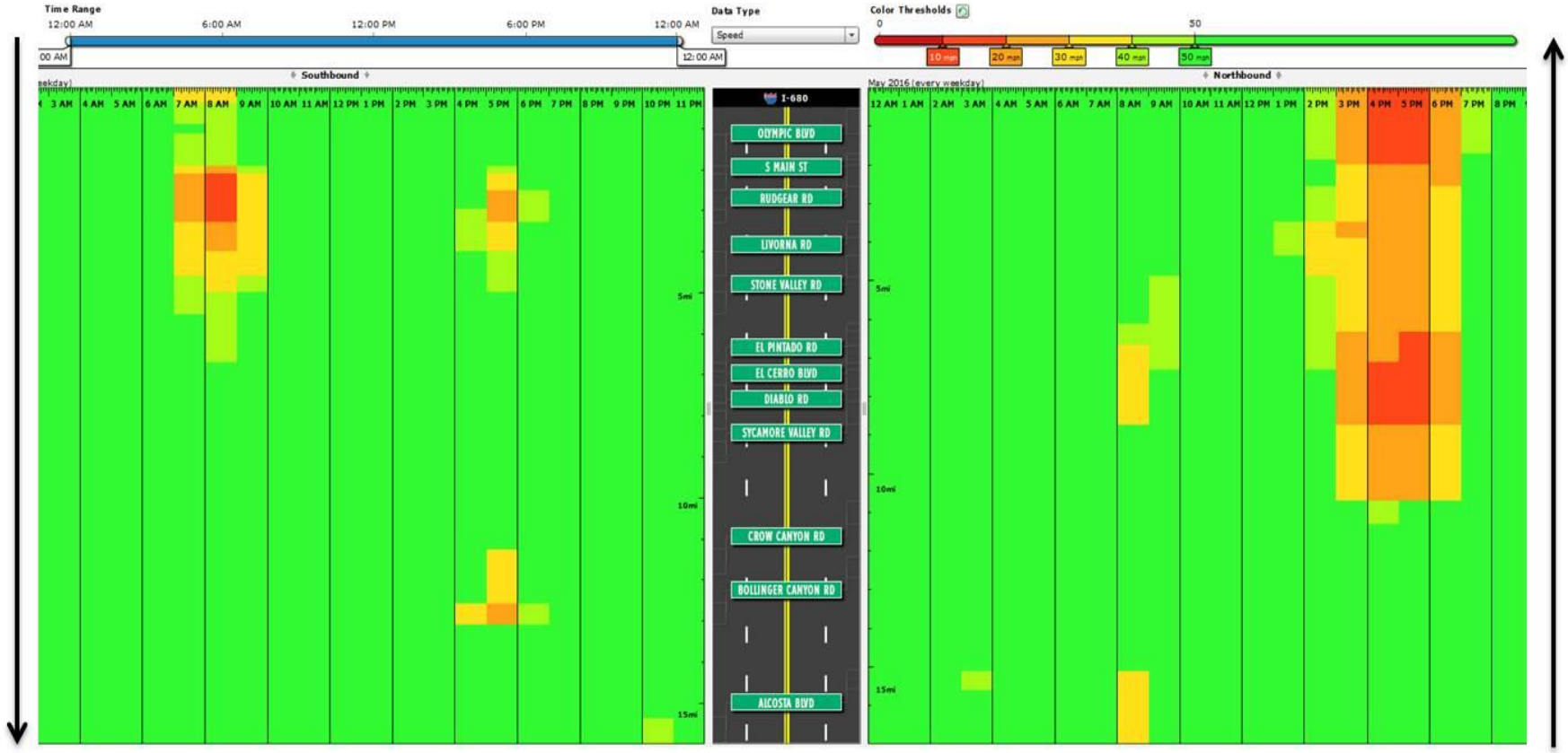

Figure 6: I-680 Congestion Profile (From Alcosta Boulevard to SR-24) May of 2016 Weekdays

Figure 6 is the continuation of Figure 5, and it shows the congestion profile for the more southerly part of the I-680 Corridor from Alcosta Blvd. to SR-24. Figure 6 also shows severe congestion in the southbound lanes in the vicinity of South Main Street, south of SR-24. The congestion starts at 7 am and continues until 10 am, with the greatest severity between 8 am and 9 am. Note that this corresponds with the lane drop in the vicinity of Rudgear Road shown in Figure 4. This congestion occurs again in the afternoon, which indicates that both the morning and afternoon southbound congestion in this vicinity are caused at least partly by the influx of vehicles from eastbound SR-24 to southbound I-680.

Figure 7 illustrates the average hourly flow through the northerly portion of the Corridor for the southbound direction during May of 2016 during the morning peak period, based on the Caltrans Performance Measurement System (PeMS) database. The Bridge is on the right side of the figure, and SR-24 is to the left. Traffic flow is from right to left. This type of figure is best interpreted as being based on the actual flow rate measured, and not traffic demand. Although there is a relationship between demand and flow, once the freeway flow breaks down into "stop and go" conditions, the flow rate becomes highly unstable, and can equal less than half of the optimal flow rate for the lanes. A drop-in flow rate can be a drop-in demand, or the onset of congestion. The figure does not show which is the case, and therefore knowledge of the corridor must be used to arrive at the correct cause for the drop. The drop-in flow rate between SR4 and SR 242 is due to the increase in the number of southbound lanes from 4 to 5, which allow for a free flow increase in speed and drop in flow rate. It indicates heavy but non-congested flow in the 4-lane section, and free flow in the 5-lane section. The flow rate gradually increases to the south as more and more vehicles enter from on-ramps until it abruptly hits a "wall" of congestion between Treat Blvd and SR-24. It is also notable that this degree of volatility in flow is never a good thing. Many traffic engineers associate this volatility with higher crash rates, which in fact is the case here and will be described in the next section on safety.

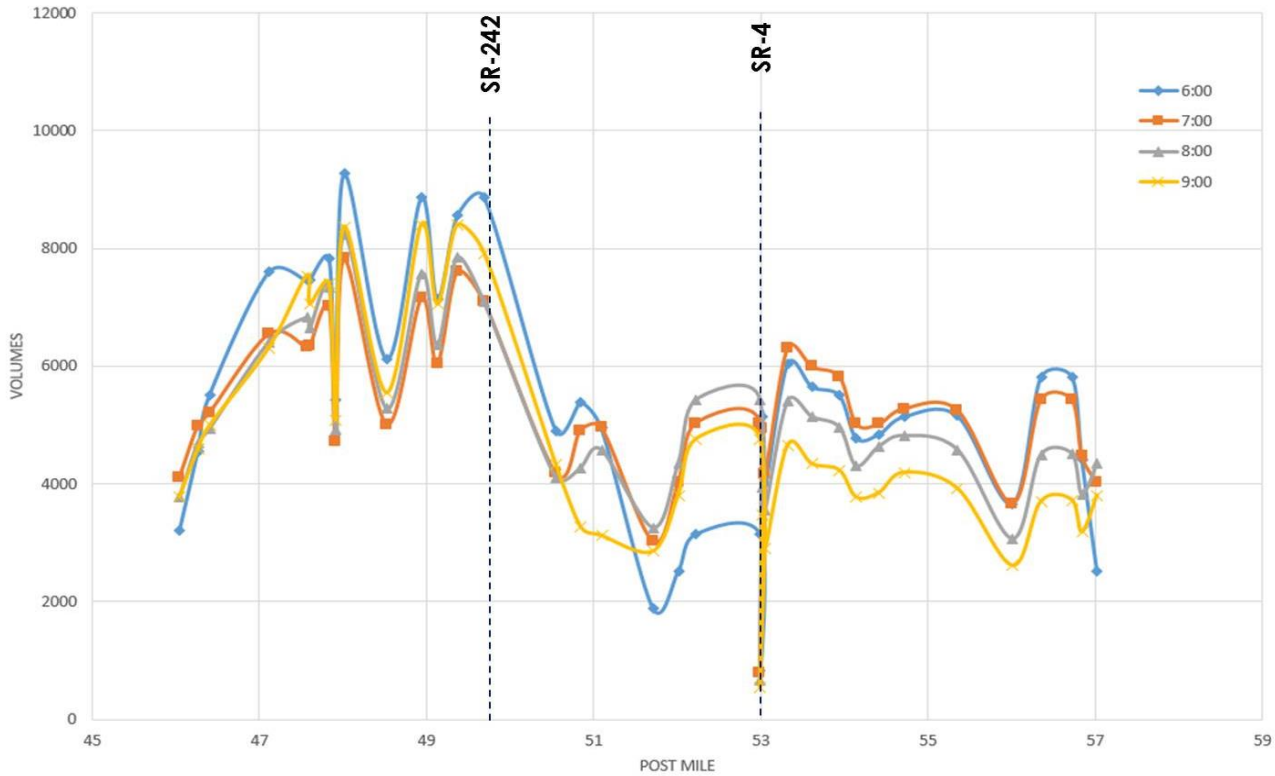

Figure 7: I-680 SB (From the Benecia Bridge to SR-24) Average Hourly Flow in May 2016 for the AM Peak Period

Figure 8 illustrates the average hourly flow through the northerly portion of the Corridor for the northbound direction during May of 2016 during the afternoon peak period, based on the Caltrans Performance Measurement System (PeMS) database. The Bridge is on the right side of the figure, and SR-24 is to the left. Traffic flow is from left to right. The drop-in flow rate between SR4 and Monument Blvd is due to several factors, including heavy off ramp volumes, lane drops, heavy on ramp volumes for northbound commuters in the Walnut Creek area, merging and weaving from SR-24 commuters exacerbated by the truck weighing station. This profound drop in flow is what causes the northbound lanes south of SR-24 to back up as shown in Figure 6.

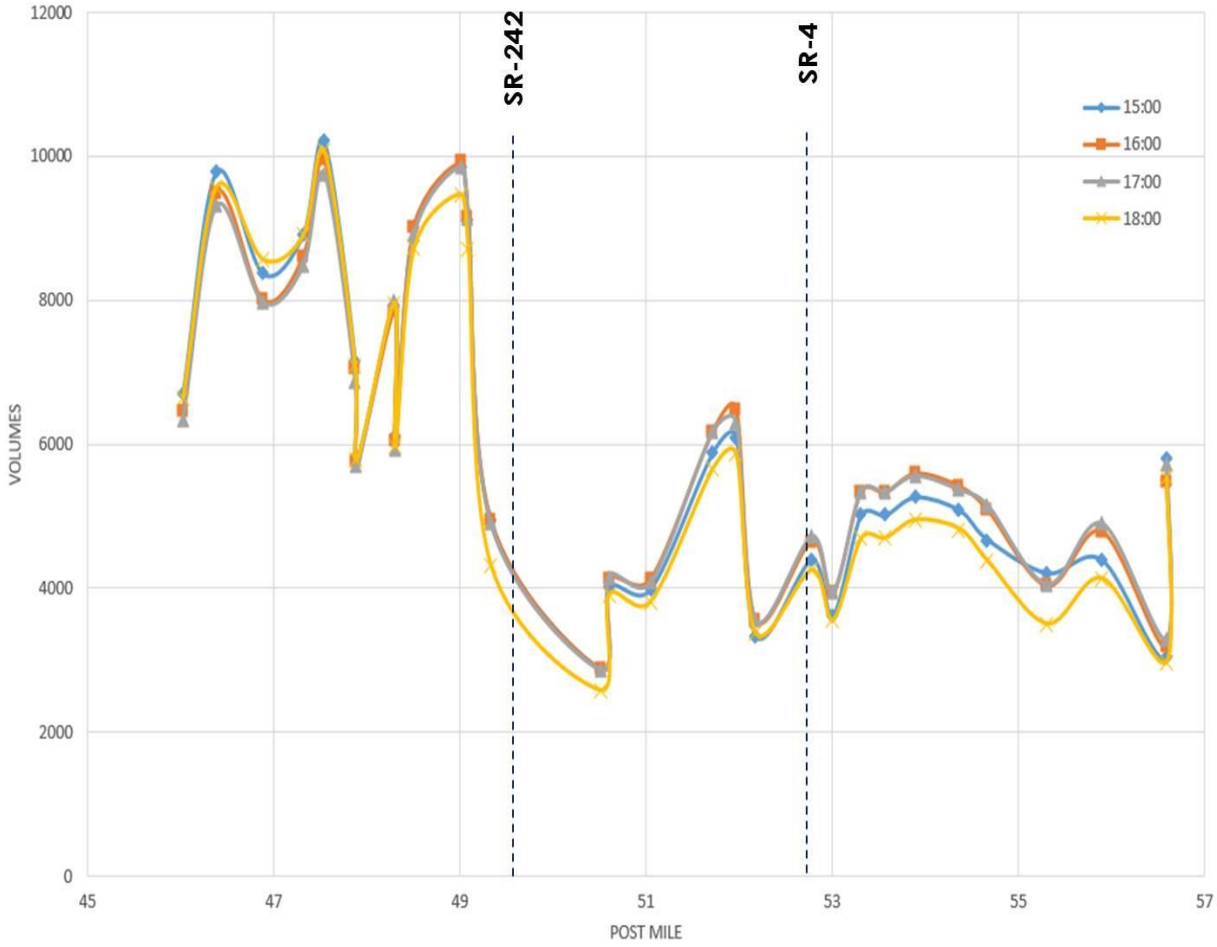

Figure 8: I-680 NB Hourly Flow Rate for May 2016 during the PM Peak Period

North of SR-24

Figure 9 shows the traffic volumes passing southbound by time of day through the entire corridor, with the orange line representing flow north of SR-24, and the blue line representing flow south of SR-24. Note that the southbound flow north of SR-24 is very high between 5am and 6 am, essentially at the theoretical maximum of just over 2,000 vehicles per hour per lane (VPHPL), or 8,000 vehicles per hour. This reflects a typical suburban condition where those who commute farthest leave the earliest. The dramatic drop in flow on I-680 between 6am and 7am north of SR-24 is attributable to two factors. Firstly, a substantial number of vehicles exit I-680 to westbound I-24 toward Oakland and San Francisco

Secondly, the fact that southbound volume south of SR-24 peaks at a much lower flow rate indicates that the heavy traffic on I-680 starts to slow due to the lane reductions in the vicinity of the SR-24 interchange. The good news depicted in Figure 9 is that adaptive ramp metering may only be necessary today in the southbound direction of I-680 north of SR-24. Between 7 am and 9 am, there are about 1,000 vehicles per hour total that need to "stored" temporarily on entrance ramps north of SR-24. This amount of metering can usually be achieved at 3 to 4 upstream ramps, depending upon the queue storage capacity at the ramps. This figure also shows that although the traffic congestion north of SR-24 is heavier throughout the day, the daily patterns of the peaks on corridor-wide southbound lanes are very similar.

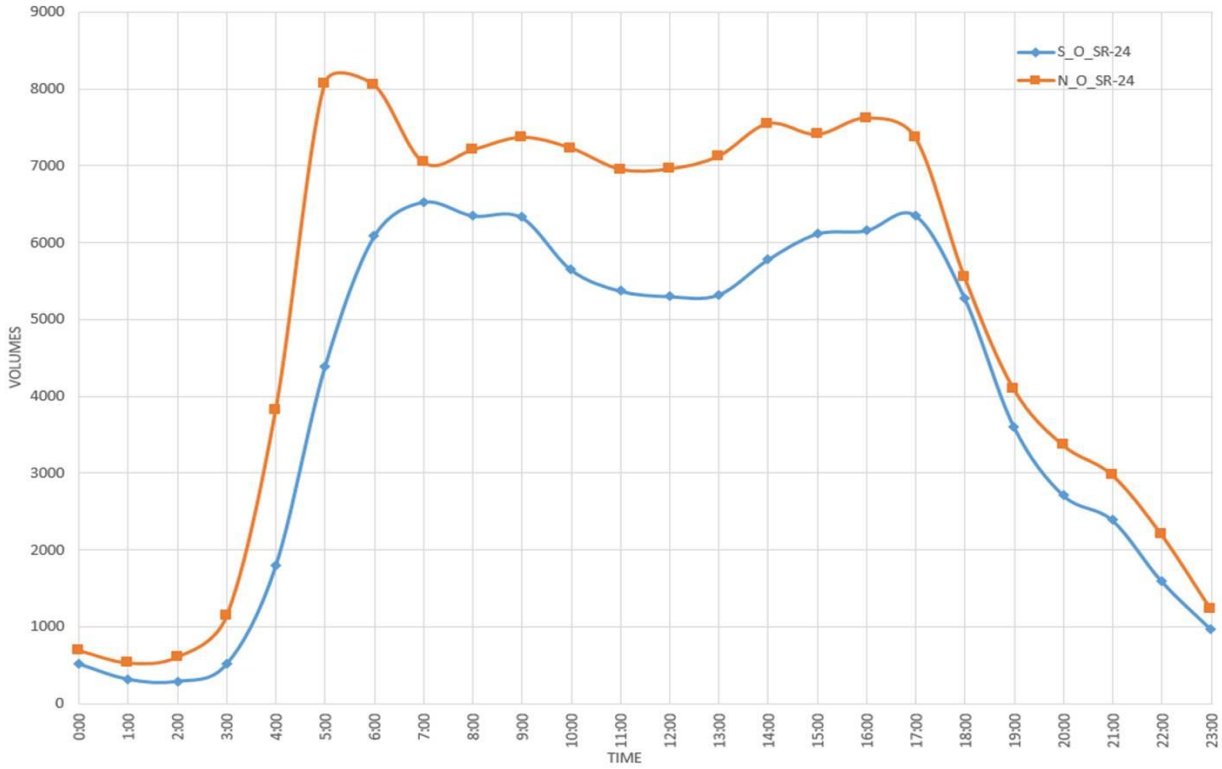

Figure 9: I-680 SB Average Hourly Flow for the year 2016

Figure 10 is the companion figure to Figure 9, showing the corridor-wide northbound lanes average daily flow by hour north and south of SR-24. The orange line representing flow north of SR-24, and the blue line represents the flow south of SR-24. Unlike the southbound lanes, traffic is heavier south of SR-24 in the am peak, and then becomes widely variant showing an extremely long congested period north of SR-24 both in terms of time and distance.

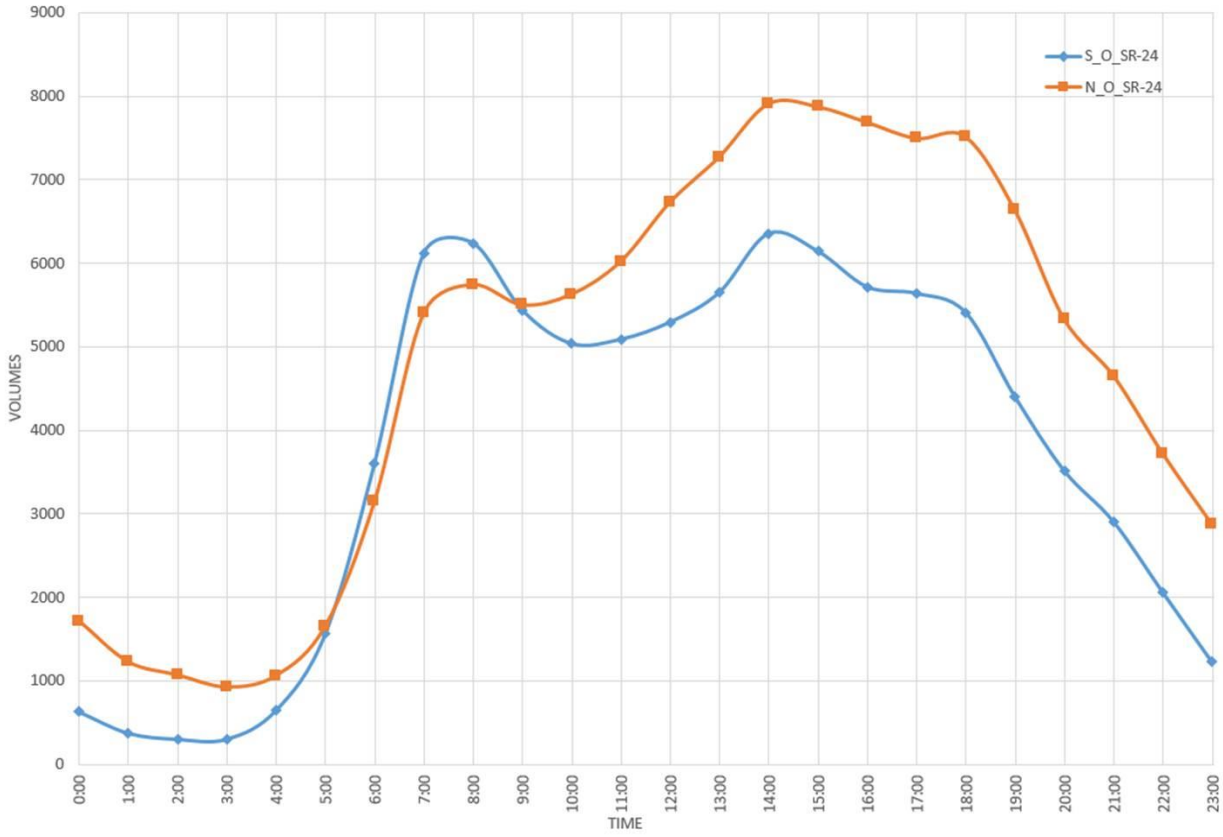

Figure 10: I-680 NB Average Hourly Flow Rate for 2016

In summary, I-680 is experiencing major and severe congestion in Contra Costa County, with the SR-24 Interchange at the epicenter of the problems. Since the impact of flows to and from SR-24 are not readily managed, Integrated Corridor Management of all the I-680 assets will be necessary to mitigate the growth of corridor congestion.

3.2.2 Traffic Safety

The volatility of traffic volume and speed on I-680 contributes to a relatively high number of crashes for a suburban freeway environment. The crashes are largely concentrated in areas of stop and go driving, which indicates a fairly high occurrence rate of rear end and end of queue type crashes. Figures 11 and 12 show the am southbound and pm northbound crashes for the same segment of I-680. Many of both northbound and southbound crashes would appear to be attributable to volatile congestion more than challenging roadway characteristics.

Figure 11: I-680 SB Number of Incidents/0.1 Miles During AM Peak Period in 2016 Weekdays

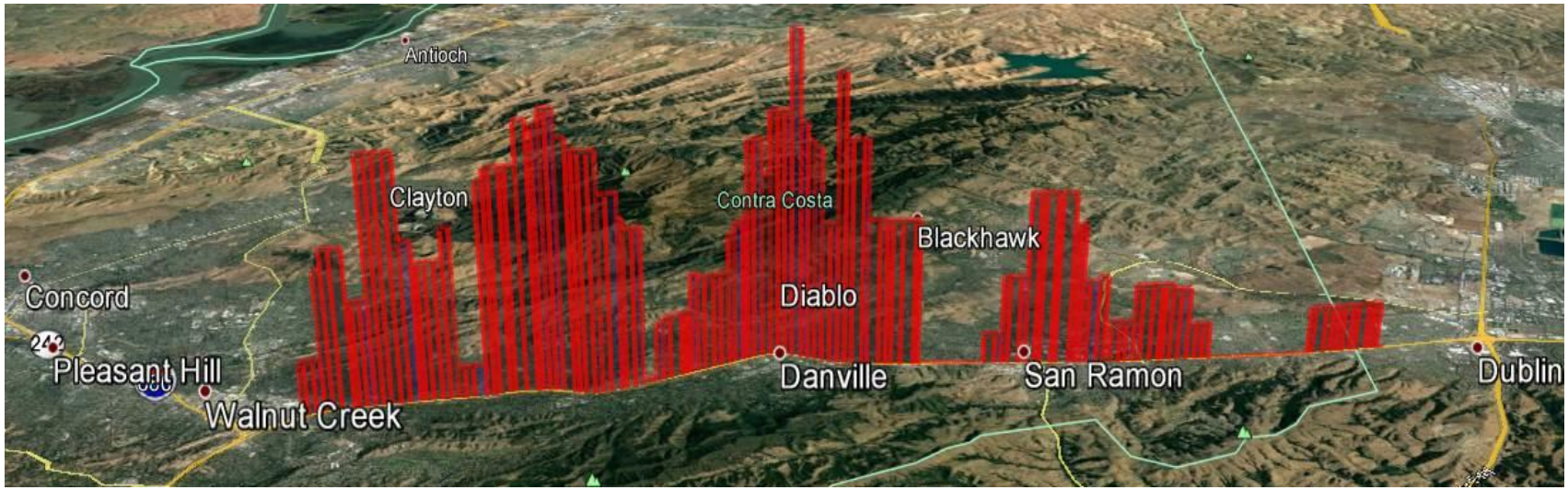

Figure 12: I-680 NB Number of Incidents/0.1 Miles During PM Peak Period for 2016 Weekdays

Figure 13 portrays a safety concern when crashes southbound crashes in the am peak would be a substantive contributor to the traffic congestion over time. Incident response in the am peak will also play a major role in addressing traffic congestion in this portion of the corridor.

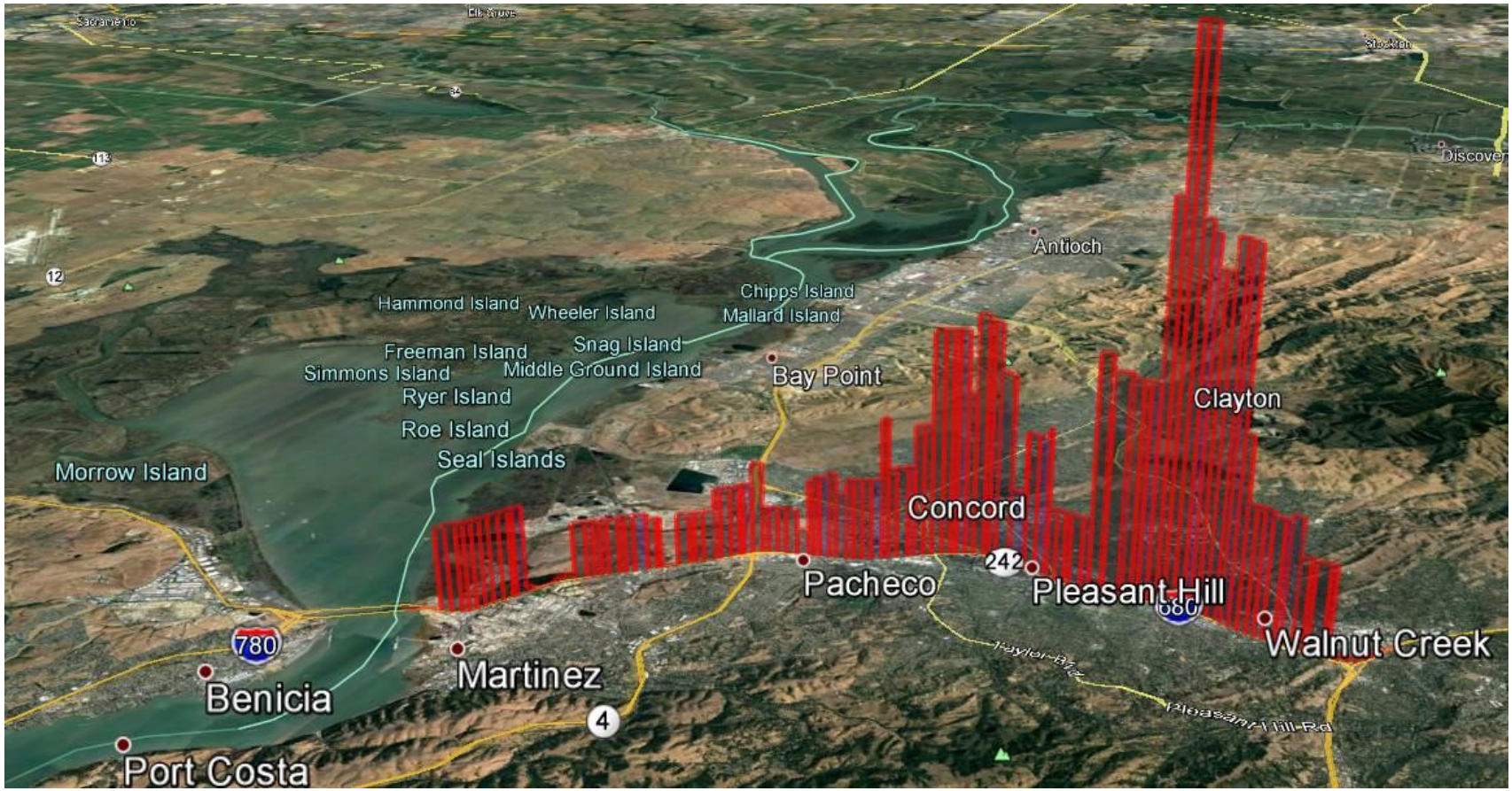

Figure 13: I-680 SB Number of Incidents/0.1 Miles During AM Peak Period in 2016 Weekdays

3.3 EXISTING SYSTEMS

In establishing the Innovate 680 Integrated Corridor Management (ICM) approach, the existence of substantive ITS equipment is a great benefit. Caltrans District 4 has made a substantive investment in ITS Devices, power, conduits, and communications.

3.3.1 Fiber Optic Communications

Caltrans has installed, and maintains, an existing 72 strand fiber optic trunk cable and associated network devices on I-680 from the Alameda/Contra Costa County line to North Main Street. The Metropolitan Transportation Commission (MTC) has a project in construction to replace and extend this 72-strand fiber cable with a 144-strand trunk cable (of which 72 strands are for Caltrans' use) on I-680 from the Alameda/Contra Costa County Line to the Benicia – Martinez Bridge Toll Plaza Building. Construction of this project is scheduled to be completed in 2017.

3.3.2 Vehicle Detection

Figure 14: Typical Mainline Freeway Detection Station Using Inductive Loops on I-680

There are 155 mainline vehicle detection stations in the corridor, using in-pavement inductance loop technology standard for Caltrans freeway ITS programs. Each station has two detectors per lane, spaced about a car length apart to allow for speed measurement as well as traffic volume counts. Traffic density can also be detected by these stations. This equates to about three stations per mile (a detection station every 1/3 mile), which is a high density of detection for open freeway by Caltrans standards. Considering an average of five lanes per station, with 10 detectors per station, there are likely over 1,500 mainline loop detectors on I-680 in Contra Costa County. Figure 14 also shows a detector station that was recently replaced on the mainline in the vicinity of Crow Canyon Road. The circular sealant pattern over the saw-cut is new, but the old circular sealant patterns can be seen where detectors evidently failed and required replacement. With close to 100% of the detectors working, the ICM concept will work, adaptive ramp metering will work, and event active traffic management may work with 1/3 mile spacing (ATM requires more frequent detection than any

other strategy). I-680 in Contra Costa has 39 on ramp detection stations, and 29 off ramp detection stations to measure traffic entering and leaving the highway at key locations.

3.3.3 Changeable Message Signs

Caltrans has seven monochrome mainline Changeable Message Signs on I-680 in Contra Costa County. These signs are controllable from the Caltrans District 4 Traffic Management Center.

Sign Name	Mile Post	Fwy Dir	Location
CM071	1.3	SB	North of Alcosta Blvd
CM092	11.76	NB	South of Rudgear
CM093	17.68	SB	South of Monument
CM094	19.03	NB	South of Concord Ave
CM056	23.4	NB	At Sewer Plant Road
CM095	23.42	SB	South of Marna Vista
CM133	25.2	NB	At Benicia on new Bridge incline

I-680 has some inconsistency in presentation of signs, using multiple display technologies for special purposes in addition to the standard butterfly; cantilever and overhead truss mount signs. These signs provide for basic communication of incident conditions; however, they do not display trip travel times.

Figure 15: Monochrome Changeable Message Sign on I-680 near the Benicia Bridge

3.3.4 Closed Circuit Television (CCTV)

There are 41 CCTV camera locations in the I-680 Corridor in Contra Costa County. The effective viewing distance of cameras of this technology is approximately one half mile. Cameras spaced one mile apart would therefore have full coverage of the space between them. The average spacing of the 41 CCTV cameras on I-680 is 0.6 miles, and only six locations are spaced greater than one mile, the greatest of these being 1.21 miles. This, by definition, is what is called "full coverage" in the ITS industry. Full coverage is usually defined as video coverage with no blind spots more than one vehicle's length. Usually blind spots occur under structures. Figure 16 is a typical Caltrans CCTV installation on I-680.

Figure 16: Caltrans CCTV TVF09 on I-680 near Crow Canyon Road

Figure 17 shows the type of pan-tilt-zoom camera with an environmentally protective housing used in the I-680 Corridor.

Figure 17: Caltrans CCTV TVF09 on I-680 with Pan-Tilt-Zoom Housing

3.3.5 Traffic Management Center

I-680 does not have a dedicated Traffic Management Center for the Corridor. TMC services are provided from Caltrans Bay Area Regional TMC in Oakland. The TMC is staffed 24 * 365, by both Caltrans TMC Operators and California Highway Patrol (CHP) personnel. (Further detail to be added, dependent upon meeting with Caltrans TMC Operations staff.)

Figure 18: Caltrans Regional TMC in Oakland

3.3.6 Arterial Traffic Signal Systems

Several of the communities through which I-680 passes have Centralized Traffic Signal Systems. Some have a TMC where centralized traffic signal systems are operated. Such agency's traffic signals are overseen from the TMC location, typically using a specialized software application loaded onto a server with communications to each intersection controller. Centralized traffic management systems allow agencies to monitor the operational status of each intersection's controller, detection and communications as well as alter the signal timing plans as necessary using predetermined timing plans or manually in response to an incident.

The key element of ICM related to the signalized intersections will be to establish a link between the adaptive ramp metering systems and nearby intersections to avoid queue spillback interference with arterial streets. Another important feature will be coordination of signal timing during major freeway incidents where traffic voluntarily diverts to an arterial, or in the case of a freeway closure where diversion is mandatory. Such provisions do not exist in a uniform way in the Corridor today.

3.3.7 Express Lanes Toll Systems

Express lanes are being constructed and made operational on I-680. These lanes are expected to be dynamically priced, such that travel time reliability based on maintaining an average speed of 45 mph or better in the peak periods can be maintained. Want to travel free in the express lanes? Carpools will continue to travel toll-free on the I-680 Contra Costa Express Lanes with a FasTrak Flex® toll tag. Carpools of 2 people will set the toll tag switch to the "2" position and carpools of 3 or more people will set the toll tag switch to the "3" position.

Figure 19: Express Lanes Under Construction on I-680

3.3.8 Traveler Information Systems and Mobile Apps

The I-680 Corridor is served by the MTC's 511 system with mobile and web services. The San Francisco Bay Area was the first region in California – and at the time the largest metropolitan area in the country – to activate a 511 traveler information system. The service now generates more than 450,000 calls and about 2.5 million Web visits each month. MTC is the coordinating agency for 511 for the nine-county San Francisco Bay Area.

4 COMPONENT STRATEGIES

The I-680 Corridor is faced with excessive and growing transportation demand, during a time when the reality of scarce resources eliminates the option of congestion relief through infrastructure expansion. Portions of the I-680 Corridor are already severely congested. Options to widen the highway, add another BART station or expand transit parking facilities are not realistic alternatives at this time. The "footprint" of I-680 in terms of its width and number of lanes for all practical purposes has reached its ultimate configuration. The structural components and adjacent property ownership characteristics make adding lanes cost prohibitive even if road building funding was available. There is clearly a mobility challenge that no one project program is going to correct. Coordination and integration at an unprecedented level will be required to reverse the trend toward gridlock. Figure 20 shows the 2020 projected travel times for the average commute in the I-680 Corridor, based on the dramatic increase experienced in just three years between 2012 and 2015. The orange arrow represents the Innovate 680 mobility program efforts to reverse and manage this escalation of congestion and loss of trip reliability.

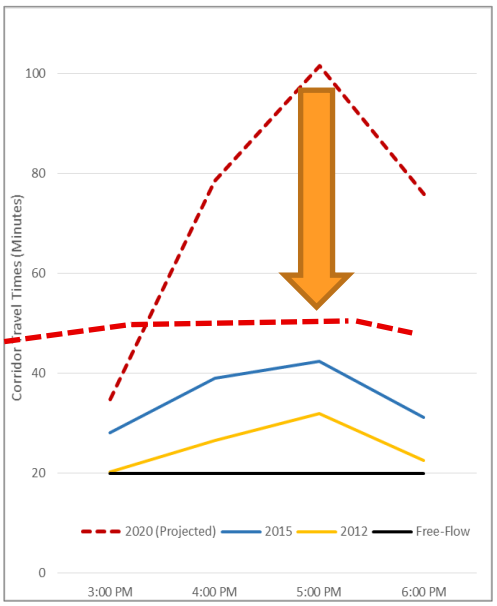

Figure 20: The I-680 Mobility Challenge

4.1 I-680 INTEGRATED APPROACH TO IMPROVING MOBILITY ON THE CORRIDOR

Key stakeholders in the region recognize that to meet the existing and emerging transportation challenges in the I-680 Corridor, issues relating to both the demand side and supply side would have to be addressed and therefore an integrated approach is required to improve mobility. Based on this philosophy seven strategies have been advanced to help mitigate the challenges.

The Innovate 680 program includes incorporating the seven strategies shown in Figure 21 into an Integrated Corridor Management System approach. Each of the seven strategies rely upon having systems in place to collect real time operational data and take actions to prolong congestion free operations, prevent the onset of "stop and go" congestion, and react to excess demand and incidents that cause delays. The system will utilize ICM technology that will leverage both highway and transit mobility assets.

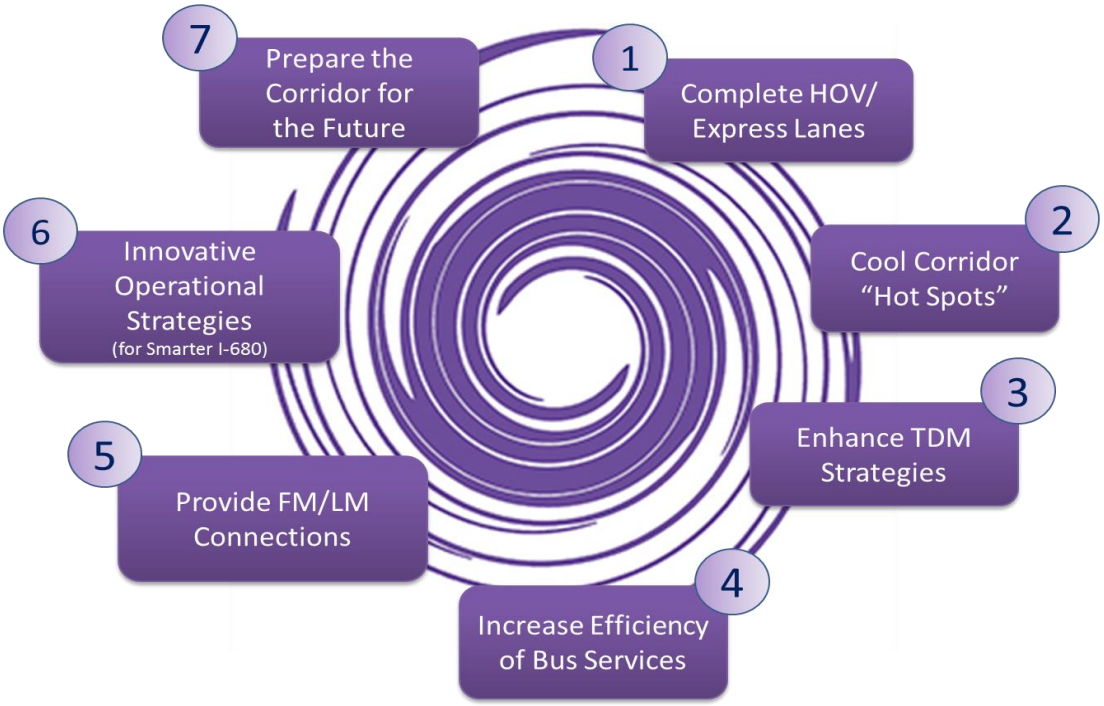

Figure 21: The Seven Component Strategies of the Innovate 680 Program

Each of the seven strategies includes multiple actions that need to be taken to address operational problems and deliver the benefits to travelers:

1. Complete the I-680 HOV/Express Lanes in Contra Costa County:

    a. Complete Southbound Express Lane: Southbound traffic, especially in the morning, will benefit from additional capacity created by the Express Lanes.

    b. Reduce the existing 7 Mile Northbound Gap: This could be the single best capital improvement available to address the sever northbound pm peak congestion.

2. Cool Corridor "Hot Spots":

    a. Add Auxiliary lanes to the mainline south of Walnut Creek. As discussed in Chapter 3, lane drops are often the culprit in the onset of hot spot congestion.

    b. Construct Collector-Distributor Road (North Main St/Treat Blvd). This element would relocate the truck weight scales and separate SR-24 travelers bound for Walnut Creek exits from mainline through traffic.

3. Enhance TDM Strategies:

    a. Promote carpooling & off-peak travel.

    b. Expand transit & bicycle incentives.

c. Promote and subsidize electric vehicle charging stations.

d. Develop a popular new mobility App.

4. Increase Efficiency of Bus Services:

   a. Implement Express Bus Services. These services are already operating, are highly successful, and can be expanded to additional key destinations.

   b. Increase Park and Ride Lots. Parking availability is a major issue in the I-680 Corridor that undermines the ability to shift travelers from highway to transit modes.

   c. Implement Bus on Shoulder. Highly successful in other jurisdictions, Bus on Shoulder (BOS) operations are a popular and low cost improvement with many benefits.

5. Provide First Mile/Last Mile Connections:

   a. Develop an App-enabled ridesharing/carpooling service.

   b. Implement and expand existing Flexible On-Demand Transit.

   c. Implement a pilot project to use Shared Autonomous Vehicles (SAV) near BART stations.

   d. Continue to facilitate Iron Horse Trail improvements for alternate modes.

6. Innovative Operational Strategies (for Smarter I-680):

   a. Expand and modernize the Intelligent Transportation Systems.

   b. Implement Adaptive Ramp Metering on select segments.

   c. Implement Integrated Corridor Mobility (ICM) Strategies

   d. Implement Active Traffic Management and speed harmonization to address crash probabilities and reduce incident related congestion.

   e. Implement Managed Lanes strategies, including the new Express Lanes, and hardened shoulders.

7. Prepare the Corridor for the Future

   a. Implement Connected and Autonomous Vehicles (CV/AV) technology on the I-680 Corridor.

b. Deploy proven Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle to pedestrian (V2P) technology, and support fleet implementation in the Corridor.

c. Develop ICM related Decision Support Systems.

4.2 INTEGRATED CORRIDOR MANAGEMENT (ICM) IN THE I-680 CORRIDOR

The seven strategies identified in Section 4.1 and detailed in section 4.3 are part of an Integrated Corridor Management (ICM)[4] approach. ICM is a relatively new way of thinking about and addressing the problems of a severely congested highway corridor. ICM has been described as a "System of Systems" where separately developed transportation assets in a corridor can be combined and operated in a highly-coordinated way that improves overall mobility. The key to implementing ICM is the combination of existing and new technologies, and integration of multiple technology sub-systems with overarching applications that share data easily across the sub-system's boundaries. Implementation of ICM involves an institutional component, where multiple agencies that share operational responsibility for the corridor participate in ICM. This higher level of integration and coordination often builds upon the foundation of incident management. ICM includes institutional cooperation during all operations, incident, and non-incident. USDOT literature describes four essential components of ICM:

"Integrated Corridor Management (ICM) is an approach to improving transportation by taking all elements in a corridor, including highways, arterial roads, and transit systems into account. According to the US Department of Transportation, "ICM seeks to optimize the use of existing infrastructure assets, making transportation investments go farther." ICM's collaborative approach better utilizes scarce resources and aligns city, county, and state transportation goals for the betterment of the region."

UC Berkeley Institute of Transportation Studies

1. **Transportation Demand Management (TDM).** – TDM addresses how travelers typically use the corridor, and involves making an effort to reduce demand on congested facilities during times of peak usage. Generally, congestion is created by travelers driving in to work from suburban homes within or beyond the corridor and then making the return trip after work to their homes. Transportation Demand Management (TDM) has been around for decades and includes things like carpooling, alternate modes, tele-commuting, and more recently dynamically priced managed lanes.

[4] *Integrated Corridor Management*, California PATH, Institute of Transportation Studies at UC Berkeley, referenced March 7, 2017, at url http://www.path.berkeley.edu/research/integrated-corridor-management

2. **Load Balancing.** – Load balancing attempts to influence how and when travelers use the individual networks in a corridor. This includes strategies like modal shift from highway to transit, reversible lanes to provide additional capacity in the direction of travel most needed, and use of roadway shoulders as travel lanes to increase capacity during peak travel times. Ramp metering can be used to balance the utilization of the arterial surface streets and freeways. Adaptive ramp metring is the newest and best of the ramp metering strategies when applied to a corridor.

3. **Event Response.** – Event response deals with how the transport network operators work together to address the impacts of planned and unplanned events that change travel patterns and network demands. Traditional incident management describes how agencies and responders work together to clear an accident site, where ICM strategies generally look at regional and corridor wide impacts of events and multiple events.

4. **Capital improvement**. For many years, the ITS mantra was "we can't build our way out of congestion." Although this may be an absolute truth, in practicality failure to improve the capacity of a network is also not likely to satisfy the public's demand for mobility. Capital improvements must be progressed in line with the principal of "infrastructure instrumentation." This means that that the best solution is to build what can be afforded, while maintaining a strong commitment to instrumenting it with electronics to measure and achieve performance goals.

Serving the population and economic growth hot spot that is Contra Costa County, I-680 is rapidly becoming one of the most challenging commutes in the San Francisco Bay Area, with the typical peak hour travel time nearly doubling since 2012. Travelers looking for alternatives to I-680 have several public transportation options. The Bay Area Rapid Transit (BART) has train stations in the cities along the northern part of the corridor, however intermodal connectivity is constrained. Transit station parking lots fill up so early in the morning that peak commuting to points west by train is limited by parking availability in Contra Costa County. Intra-county commuting by BART is limited to the norther suburbs that are home to BART stations. In addition to BART, bus transit is provided by public and private carriers. Express bus services in the north south directions use I-680, where both local and express buses are equally likely to get stuck in congestion once the freeway flow breaks down. Express lanes are being constructed for HOV and toll customers, and when they

Figure 22: Traffic Congestion in the I-680 Corridor to be addressed by ICM

become continuous through the corridor a modest improvement in the level of congestion experienced in the general-purpose lanes may result.

The existing deployment of Intelligent Transportation Systems (ITS) equipment on I-680 consists of closed circuit video cameras, changeable message signs and in-pavement vehicle detection. This equipment has been installed and is operated by the Caltrans District 4 Division of Traffic Operations (District 4). District 4 does not use the acronym "ITS" in their projects and publications. They refer to this equipment instead as Traffic Operations Systems (TOS). Today I-680 has just a subset of the TOS typically found on California freeways. As an example, there are no ramp meters on I-680. All the vehicle detectors needed to meter ramps have been installed, however the ramp meter lights, signal poles and control equipment have not.

Like many Bay-area Freeways, there is a lack of physical right of way and scarce funding for any major capacity-increasing infrastructure improvements like adding lanes or improving interchange geometry. Although ICM cannot eliminate congestion altogether, the goal will be to reduce the rate at which delay is increasing in the I-680 Corridor.

4.3 COMPLETE I-680 CARPOOL/EXPRESS LANES

4.3.1 Strategy Overview

Carpool/express lanes are specially designated highway lanes that are toll-free to carpoolers and other eligible vehicles, while also being available to solo drivers for a fee. When operated actively with changeable message signs, the FHWA calls these "managed lanes." Express lanes provide new travel choices for motorists seeking a less congested trip with more travel time reliability. Carpool/express lanes can be established by converting High Occupancy Vehicle (HOV) or carpool lanes, adding new lanes (usually in the median), or in limited cases reconfiguring general-purpose lanes provided the total number of general purpose lanes offered does not decrease. The goal of all carpool/express lanes is to provide a travel time advantage compared to the general-purpose lanes for those willing to pay a fee, travel by transit, carpool, vanpool or use a motorcycle. Travel time advantage is a function of taking less time to travel the same distance at the same time than it would take in the general-purpose lanes, as well as greater travel time reliability. Greater travel time reliability results from actively managing and monitoring the lanes in real time, and having a very effective incident detection, response and quick clearance capability. Express lanes established using federal funds are required to be actively managed to maintain an average speed of 45 mph or better during peak periods. Tolls for solo drivers can be dynamic, increasing as traffic congestion increases and decreasing as congestion decreases, and will be collected through the existing FasTrak® system used throughout the Bay Area.

Benefits to I-680 Commuters

Carpool/express lanes provide travel choices for the motoring public, improving reliability, mobility, and freeway operations. Continuous carpool/express lanes have proven to be a successful highway congestion management tool locally and in other parts of the State and Country, where they are called "High Occupancy Toll" or "HOT Lanes."

The completion of the I-680 Carpool/Express Lanes will make the best use of existing capacity and provide reliable travel times; promote carpools, vanpools, and express buses; as well as give solo drivers the choice to pay a toll to use the lanes.

4.3.2 Operational and Strategy Support Environment

To implement this strategy, the existing carpool/express lanes gap in the northbound direction would be eliminated, or at the very least shortened from 7.5 miles to less than one mile. Studies sponsored and/or published by the International Bridge Tunnel and Turnpike Association make it clear that travelers respond to convenience and simplicity over any other factor when making route and payment choices. Eliminating the gap and providing a continuous lane will dramatically increase the convenience and simplicity of using the lane. One alternative under consideration would eliminate the gap altogether, even if only during peak periods. Additional revenue generated could be channeled to share in the cost of future Corridor investments in transit such as additional park-and-ride facilities along the Corridor, shared autonomous vehicles to provide first mile/last mile connections to BART stations, and the other six strategies defined herein. Collectively these strategies will reduce the rate of increase of the number of vehicles using I-680, and provide a better trip for those that do. Planned features of this strategy include:

- Eliminating the gap in the existing carpool lanes on southbound I-680
- Connect the gap in the Northbound Express lanes.
- Conversion of all HOV and carpool lanes to carpool/express lanes.
- Vary electronic tolls with the volume of traffic (dynamic pricing) to encourage smooth traffic flow and reliable speeds, with a target minimum of 45 miles per hour in the carpool/express lane at all times including peak periods.
- Encourage customer account establishment and prevent cheating through education and enforcement. Enforcement will be aided by license plate cameras, similar to the systems at Bay Area toll bridges.

4.3.3 Operational Needs to Implement the Strategy

In implementing this strategy, the carpool/express lanes gap in the northbound direction would ultimately be eliminated. Phased deployment based on available funding would first shorten the northbound gap from 7.5 miles to less than one mile. An interim solution would be to then eliminate the short gap altogether during peak periods using managed lanes technologies. The operational needs of this strategy require the following roadway improvements:

- Extend the express lane from Livorna Road to Ygnacio Valley Road and from Lawrence Way to State Route 242. This could involve conversion of a general-purpose lane, requiring traffic analysis to determine the extent of benefits to justify conversion.
- Widen I-680 both north and south of the State Route 24 interchange to increase the length of the express lane.

- Add an outside lane from Livorna Road to Rudgear Road and from the SR-24 on-ramp to Olympic Boulevard, allowing conversion of the leftmost general-purpose lane to a carpool/express lane.
- Convert the existing carpool lane to an express lane from SR-242 to the Benicia-Martinez Bridge Toll Plaza.
- Widen I-680 to extend the express lane from SR-242 to North Main Street.
- Install a contra-flow lane between Rudgear Road and North Main Street to allow northbound traffic to utilize the southbound express lane during commute hours.

CCTA and its partner, the Metropolitan Transportation Commission (MTC) plan to complete the conversion of HOV lanes to carpool/express lanes along the I-680 Corridor by early 2020. This will create carpool/express lanes between the Benicia Bridge and the Alameda County line that are fully continuous in the southbound direction of I-680 and nearly continuous in the northbound direction. CCTA will also assess a range of improvements to minimize or possibly eliminate the gap in the northbound express lane and to address bottlenecks which affect the speed of carpools, buses and vans, as described in the next section.

4.4 COOL CORRIDOR "HOT SPOTS"

4.4.1 Strategy Overview

Congestion "hot spots" are traffic bottlenecks that recur and worsen daily congestion. In the I-680 Corridor hot spots include congestion caused by the "gap" in the carpool/express lane on northbound I-680, lane drops due to outdated interchange geometry, high-volume weaving areas in and around State Route 24, North Main Street, Lawrence Way and Treat Boulevard. Hot spots also occur at critical congested intersections on arterial streets in the Corridor and commuter parking access points.

CCTA and its partners recently analyzed these hot spots and developed a set of improvement alternatives that would ease congestion. Several of the modifications identified for northbound I-680 would require limited construction and could generally be accomplished within the footprint of the existing freeway, allowing for implementation of the improvements within five to ten years provided funding is available.

Benefits to I-680 Commuters

By modifying I-680 to improve or eliminate the most serious hot spots, CCTA can provide safer merging for motorists, ease bottlenecks that create daily delays and provide more reliable travel times along the I-680 Corridor.

4.4.2 Operational and Strategy Support Environment

A range of operational and capital improvements have been identified in analyses performed by CCTA and its partner the Metropolitan Transportation Commission (MTC). Modifications to I-680 hot spots would include implementing adaptive ramp metering at key locations upstream of congested segments, eliminating lane drops, implementing auxiliary lanes, and minimizing or possibly eliminating the existing gaps in the carpool/express lanes network described in the previous section and smoothing bottlenecks in other areas including signalized intersections.

Smoothing the North Main Bottleneck

A Collector-Distributor (C-D) road system servicing the North Main Street off-ramp, North Main Street on-ramp and Treat Boulevard off-ramp would eliminate mainline weaving and reduce the bottleneck at these locations. A C-D road system is similar to an exit ramp, but is typically longer and has the advantage of allowing drivers to pass under/over intersections, bypassing traffic signals. C-D roads also help remove weaving movements and the number of merge and diverge points from the mainline freeway.

4.4.3 Operational Needs to Implement the Strategy

CCTA and MTC have initiated an assessment of the existing and required ramp metering infrastructure and systems for the I-680 Corridor in Contra Costa, expected to be an important component of the advanced traffic management system approach. CCTA intends to further refine the alternatives developed through the project delivery process for those that can be funded and constructed.

4.5 ENHANCE TRANSPORTATION DEMAND MANAGEMENT (TDM)

4.5.1 Strategy Overview

Transportation Demand Management (TDM) is a set of programs and strategies that aim to reduce the number of vehicles using the I-680 Corridor. By reducing the "demand" side of congestion, TDM encourages more efficient use of our existing transportation infrastructure "supply" without costly expansions to support additional capacity. TDM has been recognized as one of the most cost-effective ways to counter the economic, social and environmental costs associated with increasing single-occupancy vehicle (SOV) travel and has been a priority at CCTA for over twenty years. During this period, CCTA, through 511contracosta.com, has become a national leader in innovative and effective TDM practices. CCTA will continue and expand these practices to encourage fewer vehicle trips on I-680 and vehicle miles traveled in Contra Costa County.

Benefits to I-680 Commuters

The benefits of TDM include reductions in:

- Congestion
- Parking demand
- Air pollution
- Travel costs for commuters

Many residents equate TDM and the mobility options it provides as a quality of life enhancement, including improved health, property value, safety and security.

4.5.2 Operational and Strategy Support Environment

TDM has been an accepted strategy for many years and there are many existing programs that support the strategy. Some of these programs need to be refreshed and modernized. Support elements would include:

- Regional commuter incentive promotions
- Countywide Vanpool Incentive Program
- Guaranteed Ride Home program
- Rideshare, walking and bicycling incentive program
- Student Transit Ticket Program
- Bike to Work Day
- Summer Bike Challenge
- Bike valet parking
- Electric vehicle charging infrastructure and stations
- Bicycle parking infrastructure
- Employer outreach
- Community outreach

4.5.3 Operational Needs to Implement the Strategy

Over the next eight years, CCTA intends to implement a new strategic plan with enhanced TDM program elements, currently under development, and a revitalized website in partnership with the private sector to encourage significant mode shift from single occupant vehicles (SOV) trips to private vehicle ridesharing, vanpooling and transit.

4.6 INCREASED EFFICIENCY OF BUS SERVICE

4.6.1 Strategy Overview

This strategy aims to increase the efficiency of bus services in the Corridor through improving and increasing express bus service (fewer stops and including freeway segments), implementing bus operations on shoulders along I-680, and increasing technology-based intermodal transit centers and managed parking lots along the Corridor for passenger pick-up and drop-off. Bus drivers currently refrain from using the HOV/Express lane due to the difficulty in getting in and out of the

lane, especially when the general-purpose lanes are stopped. To increase efficiency, segments of the I-680 shoulder would be modified so buses could use these lanes to bypass congestion in the normal lanes during morning and afternoon commute hours. Minneapolis, MN, has successfully and safely used bus-on-shoulder operations for more than 17 years to keep buses from being stuck in traffic, and this bus-on-shoulder transit solution could help buses navigate I-680 in a similar "express" fashion.

What Are Express Bus Operations on Shoulders?

The Bus on Shoulder (BOS) concept allows buses to use freeway shoulders during congested periods to bypass congestion in the general-purpose traffic lanes under certain specified conditions. BOS has been proven nationally; mostly on outside (right) shoulders, and a small number of inside (left) shoulders. BOS is comparatively low cost, as it can be implemented within existing right-of-way. An initial inventory and survey of shoulder width and condition will identify any lack of continuity, need for hardening or widening. Typically, BOS can be implemented relatively quickly with spot improvements, striping, signing, additional street sweeping, maintenance and driver training. There are several keys to successful BOS operations:

- Through fixed and dynamic signing, it needs to be made clear to all drivers that the shoulder is only open to buses and no other HOVs, carpools or commercial users such as taxis or UBER drivers.
- Operational rules must be established and followed by trained bus drivers regarding when they can use the shoulder. These rules include bus speed management. Typically shoulder operation is allowed at speeds as high as 35 mph, with the condition that bus drivers should only take to the shoulder when the general-purpose lanes are in a 5 to 10 mph stop and go condition. Once on the shoulder, the allowable speed differential is generally capped at 15 mph above the general-purpose lanes speed.
- Trained bus drivers will yield to emergency vehicles by vacating the shoulder, generally re-entering the rightmost general purpose lane.
- Trained bus drivers will yield to entering and exiting vehicles at on and off ramps at interchanges.
- Safety of BOS can be improved with future implementation of Connected Vehicle/Autonomous Vehicle technology. Vehicle to infrastructure (V2I) could be used to hold an entrance ramp meter in red until the bus on shoulder passes. Vehicle to vehicle (V2V) could be used to provide early warning to the bus driver of police activity on the shoulder ahead, or early warning for the bus driver to vacate the shoulder if a first responder is approaching the bus from behind.

Benefits to I-680 Commuters

BOS has multiple benefits. The BOS operations nationally have been enthusiastically supported by both bus drivers and transit passengers. It serves as a transit incentive by making transit trips in the I-680 Corridor more reliable. It provides a distinct travel time advantage to the transit rider during period of recurring and non-recurring congestion. There is a small but important benefit to the general-purpose lanes by moving the buses out, allowing for shorter headways where the buses had taken up space.

4.6.2 Operational and Strategy Support Environment

Implementation of this strategy will be characterized by the following measures:

- Travel speed differential dependent utilization of shoulders by buses (buses only use shoulders when the speed drops in the general-purpose lanes)
- Bus driver training to provide safe and reliable operation
- Instrumentation and operation of the buses on shoulders as additional managed lanes
- Striping and signing design to enhance operational understanding and safety
- No use of shoulder during non-congested conditions (e.g. average speed >35mph)
- Changeable message signs to indicate when shoulder use is acceptable and stop shoulder use when first responders are active
- Equip shoulder enabled buses with connected vehicle equipment to monitor their use, communicate with the driver and safely guide the bus through merge areas in interchanges.

4.6.3 Operational Needs to Implement the Strategy

A concept for Bus on Shoulders was developed as part of the I-680 Transit Investment / Congestion Relief Options Study. CCTA and MTC have initiated further study of this concept that includes an infrastructure and operational assessment and the development of a preliminary Concept of Operations for Bus on Shoulders operations on I-680 from SR-24 to I-580.

4.7 HIGH CAPACITY TRANSIT WITH FIRST/LAST MILE CONNECTIVITY

4.7.1 Strategy Overview

Trips that use transit services most often begin and end away from a bus stop or train station. Regardless of how efficient the transit portion of the trip may be, the ease or difficulty of getting to transit from the trip origin and to the destination from the transit terminus influence the decision to use transit. The most challenging part of the transit trip is the first segment to or from BART or the bus stop/station, and returning to the origin or home that is not served by transit. Parking garages near BART stations in the I-680 Corridor regularly become full as early as 6:30 to 7:00 am on commuter weekdays. This discourages travelers from using BART as an alternative to I-680, and has the unfortunate effect of lessening train ridership at the time it is most needed. Soon transit services in the I-680 Corridor may be complemented with the implementation of FM/LM Shared Autonomous Vehicles (SAVs). SAVs are low-speed, electric, publicly accessible shuttles currently being piloted (tested) by CCTA at Bishop Ranch in San Ramon. Where needed, additional intermodal transit stations and managed park-and-ride lots will be developed for use in conjunction with SAV concepts and similar shuttles.

Benefits to I-680 Commuters

Efficient transit service through the Corridor, as well as enhanced access to and from transit, reduces the need for Single Occupancy Vehicle (SOV) trips and reduces overall vehicle miles traveled.

4.7.2 Operational and Strategy Support Environment

Implementation of this strategy will be characterized by the following measures:

- Implementation of high-capacity transit along I-680 Corridor, potentially including modifications to run buses on the shoulder.
- Improvements to the Iron Horse Trail to make it easier and safer to bike and walk between communities.
- "Mobility-on-Demand" options, allowing residents to summon a carpool vehicle (similar to UberPOOL or Lyft Line) to get to BART or other transit centers with a touch of their smartphone.
- Deployment of low-speed, electric, publicly accessible SAV shuttles in pilot programs at GoMentum Station and Bishop Ranch, and later across the Corridor – connecting residents and employees to transit and major destinations including business centers, schools and healthcare facilities.
- Strategically located, technology-based intermodal transit centers and managed park-and-ride lots as "docking stations" for the SAV fleet.

4.7.3 Operational Needs to Implement the Strategy

CCTA will continue to enable convenient access to high-capacity transit by expanding first mile and last mile mobility-on-demand options, adding additional high-capacity buses to meet demand and identifying locations for additional parking along the Corridor for improved access to multi-modal transportation.

4.8 INNOVATIVE OPERATIONAL STRATEGIES (FOR SMARTER I-680)

4.8.1 Strategy Overview

Innovative Operational Strategies (IOS) are a suite of emerging technology-based solutions that, when combined and managed, maximize the efficiency of the roadway system in an integrated fashion. These strategies often use proven Intelligent Transportation Systems (ITS) components (or Traffic Operations Systems (TOS) in Caltrans parlance) in new and innovative ways. The recommended strategies for I-680, following industry-recognized best practices, include:

- Integrated Corridor Management (ICM): a combination of operational strategies and Decision Support Systems (DSS) that allow management of the I-680 Corridor as a multimodal system, rather than a fragmented network of individual assets, through physical and operational integration and inter-agency coordination.

- Advanced Traffic Management Systems (ATMS) use ITS or TOS devices in a coordinated way to improve traffic flow during incident and non-incident conditions. ATMS can be used to adjust traffic flow parameters across the entire Corridor formed by I-680 and the surrounding surface street grid to mitigate congestion hot spots. TOS equipment commonly deployed on Caltrans freeways will be utilized. New TOS equipment will be required to supplement the existing equipment implementation. The ATMS will include adaptive or "smart" ramp meters placed strategically at various congested interchanges along the Corridor and activated to smooth the flow of traffic merging onto I-680, reducing the traffic turbulence that causes delay and increased merging collisions. Adaptive ramp meters adjust metering rates to current traffic patterns in real time on a Corridor basis. Arterial traffic signal systems will adjust to special conditions such as ramp metering queues and incident management activity. These systems put in place to address hot spots are complimentary with the improvements envisioned in Strategy No. 6, "Innovative Operational Strategies." There are over 50 entrance ramps on I 680 in Contra Costa county, and implementation will be staged to provide the greatest traffic flow benefit using the least number of ramps.
- Active Traffic Management (ATM): ATM is lane specific management that creates the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing and predicted traffic conditions, with specialized messages that are delivered by dynamic message signs (DMS). ATM can improve safety through a technique called "speed harmonization." Speed harmonization attempts to slow traffic entering a congested segment using variable speed limit signs until the segment recovers. ATM is most often deployed using modern full color/ full matrix changeable message signs (often called Dynamic Message Signs (DMS) in other states) installed over each lane.
- Infrastructural support for future connected automated vehicles (CAV), including standardized 5.9ghz Dedicated Short Range Communication (DSRC) radios embedded in infrastructure elements as well as applications that use the emerging 5G LTE mobile communications network.
- Smart interchange technologies that implement total ramp management with adaptive metering, wrong way movement detection, control volume analysis with detection on unmetered (exit) ramps, and optional junction control measures on severely congested interchanges.
- Full video coverage and image processing for event recognition on all lanes and shoulders.

Benefits to I-680 Commuters

IOS maximizes the efficiency and travel reliability of the I-680 Corridor. Through the use of technology and integrated systems – and the automated deployment of strategies – the delays that would occur if operators deployed strategies manually will be minimized. IOS increases throughput, enhances safety, and reduces emissions. With traffic congestion growing, the public expectations are high that the low cost IOS measures will be fully leveraged to mitigate delays and reduce the rate of increase on travel times.

4.8.2 Operational and Strategy Support Environment

Implementation of this strategy will be characterized by the following measures:

- Adaptive ramp metering at select ramps with a corridor metering algorithm and interties to arterial intersections and Express Buses.
- Speed harmonization to stabilize traffic flow
- Queue warning systems to advise of stalled traffic ahead
- In-vehicle driver information systems to provide motorists with information on traffic conditions ahead
- Dynamic lane use management for "traffic balancing"
- Decision Support Systems (DSS) to manage the Corridor more efficiently
- Cooperative policy coordination and alignment
- Improved freight operations to incentivize Corridor usage during off-peak hours
- Sensor and communications infrastructure and ITS instrumentation

4.8.3 Operational Needs

CCTA plans to initiate the IOS program and develop a Concept of Operations outlining comprehensive strategies for full multi-phase implementation with input from Corridor stakeholders.

4.9 PREPARE THE CORRIDOR FOR THE HIGH-TECH FUTURE

4.9.1 Strategy Overview

Transportation technology is evolving quickly, and several connected vehicle applications are already being tested with positive results around the globe. "Level 2" and "Level 3" autonomous vehicles (providing at least two simultaneously autonomous features and full autonomous control in certain conditions, respectively) are here, and new features are being introduced by auto manufacturers and technology companies on a weekly basis. The very near future will likely see CV applications and AV technologies implemented on our roadway infrastructure system in an evolutionary process.

CCTA is preparing the I-680 Corridor to accommodate the evolution of CV applications and AV technologies for improved traffic flow by building new and upgraded vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications, building on its experiences managing the largest secure testbed in the country, GoMentum Station (www.gomentumstation.net).

Benefits to I-680 Commuters

Increased throughput, from 2,000 vehicles per hour per lane to 3,300; safety and incident prevention; reduced need for new infrastructure; travel time dependability; more efficient travel through balanced traffic flow and traffic smoothing; and improved energy efficiency with reduction in greenhouse gases.

4.9.2 Operational and Strategy Support Environment

Implementation of this strategy will be characterized by the following measures:

- Prototype applications of connected vehicles, including express buses and trucks
- Provisions of Dedicated Short Range Communications (DSRC) along the Corridor
- Installation of digital and communication components as part of infrastructure improvements
- Establishment of interoperability for data exchange
- Provisioning of V2I safety applications
- In-vehicle speed harmonization and management
- Installation of roadway sensors
- Commercial vehicle enforcement and management
- Priority assignment for emergency vehicles and CHP

4.9.3 Operational Needs

CCTA is undertaking early deployment of CV applications and AV technologies through its comprehensive GoMentum Station program, in collaboration with Corridor stakeholders and partner agencies. Deployment along the I-680 Corridor will involve early controlled demonstration and field operation testing, benefits assessment through the collection and analysis of real-world data along the Corridor and assessment of engineering architecture and design.

5 CONCEPT EXPLORATION

As discussed in Section 1, the concept exploration is the very first design step in the Caltrans systems engineering process, where needs have been identified and a solution set is established for implementation. The solution set for Innovate 680 is varied. How can the "Component Strategies" described in Section 4 be organized and woven into an integrated approach, where the maximum benefit for investment will be achieved considering funding constraints?

The Innovate 680 program requires development of a strategic deployment plan consisting of multiple projects to implement component strategies that will deliver benefits early, and build a foundation for the other components to be deployed over time. One thing all of the seven component strategies have in common is they are all data dependent. In order for the component strategies to be implemented, the real time operational systems that capture data, process it and execute actions based on the data must be created. These systems require planning, design, and construction of systems elements. In this Section, the available technologies to create these systems are described. The related component strategies enabled by the technologies are identified. There is more than one possible approach, making the "exploration" of various possibilities essential. The concept to be developed through this exploration will describe how the real time operational improvements identified in Section 4 will be woven into a "system of systems" Integrated Corridor Management (ICM) solution as described in Section 4. The technologies to be deployed to implement the component strategies are described as subsystems. This is followed by a discussion of the nature of the planned changes and a justification for them.

5.1 MAPPING COMPONENT STRATEGIES TO SYSTEM ELEMENTS

The component strategies described in Section 4 are listed in Table 1. Each component has been provided with an assessment of its potential based on four comparative attributes:

1. ICM Component: This is a "yes or no" attribute. It is either an ICM element, or not. Only the three very general component headings were not ICM components, but several of their sub-components are ICM elements. As an example, "Increase Efficiency of Bus Services" is not considered an ICM element, but the subcomponent "Implement Bus on Shoulder" is an ICM element.

2. Relative Cost: This is a somewhat subjective attribute, in that precise cost estimates have not been prepared for all the components. Relative means relative to other elements in this table. The cost was rated as "high", "medium" or "low" depending upon the caparison with other components. As an example, "Implement Active Traffic Management" is given a medium cost rating because it typically involves installing dynamic message sign gantries at fairly frequent intervals, whereas "Implement Adaptive Ramp Metering on select segments" is rated low in relative cost because the equipment necessary to install is comparatively less expensive and the entire detector subsystem needed tom operate it is already installed.

3. Relative Benefit is also a subjective attribute. In the case of benefits, the opinions expressed by the key institutional stakeholder group during the Innovate 680 meetings have been considered. In this case, the component may be rated to have a high benefit compared to others if it is relatively easy to implement.

4. The Status attribute simply reflects some indication of whether the component is already being implemented, as many of these are.

Table 1: Component Strategies Criteria

Component Strategy	ICM Component	Relative Cost	Relative Benefit	Status
Complete the I-680 HOV/Express Lanes in Contra Costa County	Yes	High	High	Underway
Cool Corridor "Hot Spots":	No	High	High	Underway
Enhance TDM Strategies:	No	Low	Medium	Underway
Increase Efficiency of Bus Services	No	Low	Medium	Underway
Increase Number of Park and Ride Lots	Yes	High	High	Planning
Implement Bus on Shoulder	Yes	Low	Medium	Design
Pilot project to use Shared Autonomous Vehicles (SAV) near BART stations.	Yes	Low	High	Testing
Innovative Operational Strategies (for Smarter I-680):	Yes	Low	High	Planning
Expand and modernize the Intelligent Transportation Systems.	Yes	Low	High	Underway
Implement Adaptive Ramp Metering on select segments	Yes	Low	High	Underway
Implement Integrated Corridor Mobility (ICM) Strategies	Yes	Low	High	New

Component Strategy	ICM Component	Relative Cost	Relative Benefit	Status
Implement Active Traffic Management	Yes	Medium	High	New
Implement Managed Lanes strategies	Yes	Medium	High	Underway
Implement (CV/AV) technology	Yes	Low	High	New
Deploy proven (V2V), (V2I), (V2P) technology	Yes	Low	Medium	New
Develop ICM related Decision Support Systems.	Yes	Low	High	New

The next step in concept exploration was to conduct a multi-attribute utility analysis. Table 2 is the result of the analysis based on numerical data assigned by the authors. These rankings may change based upon additional input from stakeholders.

Table 2: Multi-attribute Utility Analysis for Ranking Components

	20%		40%		30%		10%		100%
Component Strategy	ICM Component		Relative Cost		Relative Benefit		Status		Rank
Implement Adaptive Ramp Metering on select segments	Yes	10	Low	10	High	9	Underway	9	9.6
Implement Integrated Corridor Mobility (ICM) Strategies	Yes	10	Low	10	High	9	New	7	9.4
Implement Bus on Shoulder	Yes	10	Low	10	Medium	7	Design	9	9
Develop ICM related Decision Support Systems.	Yes	10	Low	9	High	9	New	6	8.9
Expand and modernize the Intelligent Transportation Systems.	Yes	10	Low	9	High	8	Underway	7	8.7
Implement (CV/AV) technology	Yes	10	Low	9	High	7	New	7	8.4
Innovative Operational Strategies (for Smarter I-680):	Yes	10	Low	8	High	8	Planning	7	8.3
Pilot project to use Shared Autonomous Vehicles (SAV) near BART stations.	Yes	10	Low	8	High	7	Testing	8	8.1
Deploy proven (V2V), (V2I), (V2P) technology	Yes	10	Low	8	Medium	7	New	7	8
Implement Active Traffic Management	Yes	10	Medium	7	High	7	New	7	7.6
Implement Managed Lanes strategies	Yes	10	Medium	6	High	8	Underway	8	7.6
Complete the I-680 HOV/Express Lanes in Contra Costa County	Yes	10	High	1	High	10	Started	8	6.2
Increase Efficiency of Bus Services	No	0	Low	8	Medium	7	Started	8	6.1
Enhance TDM Strategies:	No	0	Low	7	Medium	7	Underway	8	5.7
Increase Park and Ride Lots	Yes	10	High	2	High	8	Planning	3	5.5
Cool Corridor "Hot Spots":	No	0	High	3	High	10	Started	8	5

The Multi-Attribute Utility Analysis is a useful tool for ranking alternatives, and also evaluating the effect of weighting criteria. Note that in Table 2 a percentage is listed above the subjective criteria column. As an example, the criteria for "Relative cost" is given the greatest importance at %40 percent. If for example this was reduced to 10%, and benefit was increased to %50, the ranking would be very different. This is often called "sensitivity analysis" to see what happens based on the evaluating group's priorities.

Having established an initial ranking of the components in this draft report, information is provided in the following sub-sections on some of the more highly ranked components.

5.2 ADAPTIVE RAMP METERING

An adaptive ramp metering (ARM) operation seeks to optimize a multiple-ramp section of a highway, often with the control of a bottleneck as the goal. The operations strategy at any one of the ramps is similar to local traffic responsive ramp metering; however, multiple ramp congestion response strategies can be deployed based on modeled conditions through the use of software with a virtual intelligence engine. The principal goal of adaptive ramp metering is to maintain optimal freeway flow by measuring the number of vehicles on the mainline, and reducing ramp entrance volumes that would otherwise cause the freeway to break down into stop and go operations.

A capability-enhanced PARAMICS simulation model has been used in an evaluation study of adaptive ramp-metering in a simulation environment over a stretch of the Interstate 405 (I-405) freeway in California, under both recurrent congestion and incident scenarios. Simulation results show that adaptive ramp-metering algorithms can reduce freeway congestion more effectively compared to the fixed-time control. Compared with fixed ramp metering operation, adaptive ramp-metering operation could reduce the total vehicle hour travelled (VHT) by up to 9 percent under recurrent congestion conditions and up to 2 percent under incident scenarios.

A macroscopic model was developed for SR-4 using FreQ software. By implementing dynamic ramp metering at Willow Pass W on-ramp, Willow Pass diagonal on-ramp and San Marcos loop on-ramp for the westbound direction, the model results show approximately 14% increase in average speed and approximately 13% reduction in freeway vehicle-hour traveled, with approximately 57% reduction in ramp delay.

Thirty nine of the fifty-two entrance ramps on I-680 have already been designed and the detectors have been installed to accomplish local ramp metering. Essentially, the adaptive ramp metering project component can be added to a ramp metering project that is already underway. The Innovate 680 project need is to install the controllers, ramp metering and queue warning displays, and establish an interconnection where necessary with traffic signal controllers at adjacent intersections.

5.3 INTEGRATED CORRIDOR MANAGEMENT

Integrated corridor management (ICM) leverages all available capacity across all modes of travel to move people and goods along a corridor. This requires the use of real-time system information, predictive tools, and decision support systems to balance demand across different transportation assets. This fosters more dynamic and fluid travel decisions with high reliability to meet each traveler's mobility needs. An integrated approach may require rerouting traffic, changing operational parameters (signal timing, ramp closures, etc.) and or mode shift. ICM facilitates access to excess capacity in a mode or route and can help minimize congestion. This in turn will reduce delays and improve air quality because of fewer emissions.

A recommended project approach would be for CCTA to learn more about the ICM projects and software Caltrans already has underway. The operational role of CCTA will be to gather all data, evaluate performance in an automated way with the aid of a Decision Support System, and communicate with operators regarding proposed improvements. This would require integration of stakeholder systems for information exchange and need to develop MOUs or agreements to facilitate its implementation.

5.4 BUS ON SHOULDER OPERATION

The bus on shoulder (BOS) operations concept would allow buses to run on the shoulder of segments of I-680 that can accommodate it during peak congestion periods. BOS are typically implemented on corridors with significant recurring congestion since more of the benefits accrue as speeds drop drastically to stop-and-go conditions. The inside or outside shoulder may be used even though the latter is the more common method. Restrictions may be placed on the use of the shoulder for other vehicles except in emergencies. Pavement markings and signs are used to provide information to travelers on for instance hours of operations of BOS and when shoulders can be used. The protocols for when buses can use the shoulder may vary from one jurisdiction to another. Generally, bus drives can use the shoulders whenever there is significant congestion on the mainline and speeds have dropped. The potential benefits to be derived from this concept include[5] travel time savings, running time savings, travel time reliability, and some improvement in ridership. Proper design and driver education are required to assure smooth implementation.

A recommended project approach for CCTA will be to implement BOS on contiguous shoulder segments, as part of the ICM solution. This means that the operation would be controlled and managed with electronic signing, connected vehicle technology, and integration with the ramp metering system. This will allow an efficient and safer operation, where ramp meters will hold vehicles on the ramp while the bus passes through an interchange on the shoulder.

[5] http://www.tcrponline.org/PDFDocuments/TCRP_RPT_151.pdf accessed March 27, 2017

5.5 DECISION SUPPORT SYSTEMS

A decision support system as the name suggests is a software tool that mimics human experts and assists with analysis and decision making. It requires integration at institutional, operational, and technical levels for sharing and distribution of information and strategies to manage both the demand for and supply of transportation. Traffic management operations usually rely on real-time traffic data to observe the traffic status, detect incidents, and make a decision on which actions to undertake for improving network throughput or for reacting to incidents. The impact of such actions may only be known after a certain time, once updated traffic data arrives at the Traffic Management Center (TMC). Such a process too often leads to a "trial-and-error" management process that we term "reactive". A better approach would be a "pro-active" process with a design support system, allowing the operators to evaluate in advance the likely consequences of their actions before implementing them in real life. Transit operations decision support systems (TODSS), deployed at Pace Suburban Bus in Northern Illinois, reduced false and low priority incident reports sent to dispatchers by 60 percent, allowing dispatchers to focus on higher priority incidents.[6] Decision support systems can also be used to support integrated corridor management for a more proactive management of multimodal transportation corridors to maximize throughput.

A project approach for I-680 would be to develop and implement decision support that meets CCTA's needs. Figure 23 depicts an architecture based on DSS concepts that would improve operations in the I-680 Corridor, not just for CCTA, but for Caltrans, BART, and other key transportation asset owners.

5.6 TRAFFIC OPERATIONS SYSTEMS

Traffic Operations Systems also known as Intelligent Transportation Systems (ITS) involves the deployment of standardized ITS devices in a corridor to provide basic freeway management. Caltrans typical TOS instrumentation consists of inductive loop vehicle detectors, Closed Circuit Television (CCTV) cameras, Changeable Message Signs (CMS) and Ramp Meters tied together with a fiber optic cable network. I-680 has all but the ramp meters installed. The CCTA project to expand and modernize the TOS would include adding the ramp meters, placing additional CCTV cameras where needed to provide monitoring of ramp metering queues, and the design of specialized Dynamic Message Signs (DMS) for some of the ICM strategies that are not currently in use by Caltrans. The result will be improvements in the integration of interagency systems for data or information sharing, coordination, and communications to field devices to monitor and control traffic.

[6] Based on the evaluation of the TODSS prototype development at Pace Suburban Bus in Northern Illinois, February 2010, http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/18ADA06C347964E3852578B6006B7098?OpenDocument&Query=Home,%20U.S.%20DOT,%20Office%20of%20the%20Assistant%20Secretary%20for%20Research%20and%20Technology, accessed August 2016.

Figure 23: Exploration Concept for Decision Support of I-680

5.7 ARTERIAL TRAFFIC SIGNAL SYSTEMS

Arterial traffic signal systems manage conflict points in the roadway network to enhance safety, mobility, and environmental emissions. A poorly implemented system will lead to significant congestion that can impact adjacent roadways including freeways. Traffic signal systems vary significantly in the way they manage traffic. They can be fixed pre-timed systems that are not responsive to traffic demand or have time of day coordinated patterns with fixed cycle lengths that are responsive to traffic demand. Adaptive signal control systems use strategically placed advance detection systems and algorithms to manage traffic effectively and efficiently and was one of the focus technologies for FHWA's Every Day Counts initiative. The benefits of adaptive systems[7] include equitable distribution of green time for all traffic movements, improvement in travel time reliability by tunneling traffic through greenlights in the corridor, reduces congestion, and prolongs effectiveness of traffic signal timing.

Although integration with traffic signal systems is not specifically called out in the list in Table 1, implementation of several of the other components require this integration to be effective. It is anticipated that in following the next step of the Systems Engineering process, the development of a Concept of Operations, meetings will be held with I-680 Corridor municipalities adjacent to I-680 to gather information on their signal systems and coordinate with better knowledge of their operational capabilities and needs.

[7] https://www.fhwa.dot.gov/innovation/everydaycounts/edc-1/asct.cfm accessed March 27, 2017

5.8 CONNECTED VEHICLE SYSTEMS

Connected vehicles are vehicles with the capability to communicate with each other and the roadway infrastructure or other devices to exchange information about position, speed, trajectory, and other parameters so that all entities are aware of each other and can optimize mobility and safety. Connected vehicle technology has the potential to significantly impact operations and yield a plethora of probe data that can give the exact status of the transportation system and foster more reliable real-time traffic management strategy. Some of the benefits anticipated and reported by the AASHTO deployment analysis report[8] and the field infrastructure foot print analysis report [9]include the following: reduce the likelihood of collisions at intersections (intersection collision avoidance systems); reduce the likelihood of forward and lateral (lane change and merge) collisions; reduce the likelihood of secondary crashes; reduce the likelihood of road departure crashes; provide more accurate and timely road condition alerts (motorist advisories and warnings with emergencies, inclement weather, curve speed, oversize vehicle, etc.); reduced energy consumption and vehicle emissions (dynamic eco-routing); and seamless multimodal travel. Furthermore, connected vehicle technology can increase the functional capacity of roadways when the headways are reduced.

5.9 DYNAMIC PRICING OF EXPRESS LANES

Dynamic pricing of express lanes utilizes variable toll rates depending on congestion in the corridor to provide reliable travel times for traffic on managed lanes. High occupancy vehicles including buses, carpools, and vanpool users can enter express lanes for free while single occupancy vehicles have to pay a toll.

5.10 ACTIVE TRAFFIC MANAGEMENT

Active traffic Management is the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing traffic conditions. There are several tools that are used to achieve this objective and they include speed harmonization, automated speed enforcement, freeway shoulder use, dynamic lane markings, dynamic merge control, queue warning, junction control, work zone management and dynamic rerouting.

5.11 PARKING MANAGEMENT SYSTEMS

Park and Ride facilities are public transportation stations that allow commuters and other people traveling into city centers to leave their personal vehicles in a parking lot and transfer to other modes of travel such as transit (bus, rail system) or carpool for the rest of their trip. The vehicle is stored during the day and retrieved when the commuter returns. Park-and-ride facilities allow commuters to avoid a stressful drive along congested roads and a search for scarce, expensive city-center parking. They may well reduce congestion by assisting the use of public transport in congested urban areas.[10] Smart parking systems can provide real-time information about

[8] AASHTO Connected Vehicle Infrastructure Deployment Analysis. Final Report June 17, 2011
[9] National Connected Vehicle Infrastructure Footprint Analysis Deployment Concepts. Final Version 2 September 20, 2013
[10] https://en.wikipedia.org/wiki/Park_and_ride, accessed August 2016.

parking availability, communicate this to the public and guide them to available parking spaces. Travelers can remotely interact with parking management systems to make advance reservations for parking by using smartphones, the web or in-vehicle navigation systems. Parking management systems can also dynamically change parking pricing in response to demand to encourage use of transit and thereby reduce congestion. Parking management systems can reduce travel time by 9%[11].

5.12 TRAVELER INFORMATION SYSTEMS

Traveler information consists of transportation network monitoring and the methods used to obtain and disseminate information to travelers. Traveler information may include traffic conditions such as congestion, incidents, roadway weather conditions, travel time, AMBER alerts, transit schedules or status, or work zones information. Traveler information requires accurate information to enable travelers make informed pre-trip and en-route decisions about the best modal choice, routes, and departure times to meet their mobility needs. Drivers who use alternate routes to avoid congested roadways or locations with for instance incidents help to reduce the duration of congestion and the negative outcomes thereof. From a safety perspective, drivers can avoid hazardous or threatening situations when informed of adverse weather conditions.

5.13 FIRST MILE/LAST MILE SYSTEMS

Using Shared-Autonomous Vehicles (SAV) for taking passengers to key transit hubs such as BART stations, Amtrak stations, bus stations, ferry stations, and take them back home from that station is a first mile/last mile solution that can increase ridership of transit vehicles and reduce traffic by using multimodal options to meet mobility needs. Autonomous Vehicles (AV) are considered to be safer than regular vehicles with their capability of preventing accident and can reduce fuel emission when AV vehicles platoon or increase throughput from standard 2000 vehicles per mile per lane to more due to their platooning capability. The Connected Vehicles (CV) can even take platooning a further step by communicating with the nearby vehicles, infrastructure, pedestrians, and bikes. The majority of expected benefits of using CV are described by U.S.DOT as part of CV Program and categorized into Safety, Mobility, environment, road weather, agency data, etc.

A Monte Carlo style simulation model was used to quantify the benefits of connected vehicle technology indicated that connected vehicle technologies can increase capacity by 20 to 50%.[12] Another study, using a microscopic traffic network simulator and emissions model to emulate traffic at three signalized intersections in the town of Amherst, NY, indicated that a

[11] https://ntl.bts.gov/lib/54000/54200/54247/BCLL_2014_Combined_JPO-FINAL5.pdf accessed March 27, 2017

[12] Experience with simulation modeling used to evaluate connected vehicle technology, September 7, 2011,http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/70212CAA6C95BA5D85257B510055CD6E?OpenDocument&Query=Home, accessed August 2016.

network of autonomous vehicles with full market penetration can use intelligent intersection data to manage approach speeds and reduce average vehicle delay by 85%.[13]

5.14 RECOMMENDED SYSTEM

Based upon the exploration of relevant concepts, guided by the vision adopted in Section 2, building on the existing conditions described in Section 3, incorporating the desired component strategies discussed in Section 4, and ranking the strategies combined with their enabling technologies described in this Section, an initial system recommendation is possible. Figure 24 depicts a recommended system as a starting point for the Innovate 680 program.

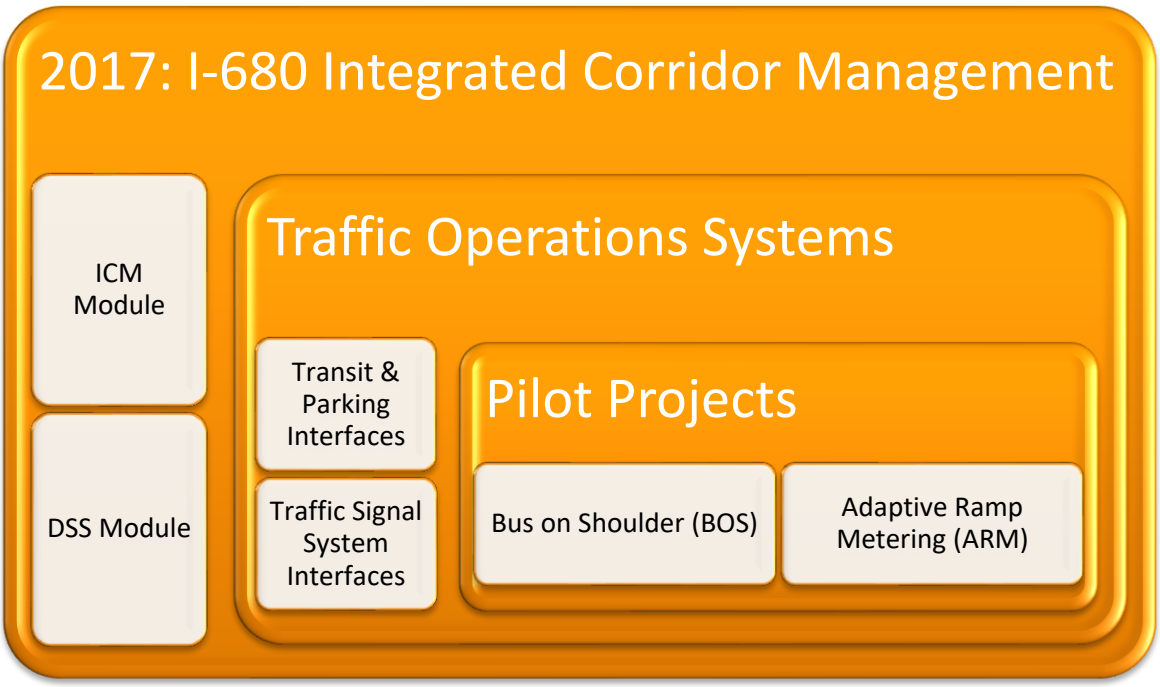

Figure 24: I-680 Recommended Initial System Based on Concept Exploration

Figure 24 reflects a foundational first concept for Innovate 680 that will fit within budgetary constraints, and accomplish the highest level of benefits achievable in the Corridor at this time. It represents a considerable investment in the future, and not just minor spot improvements. The largest rectangle in Figure 24 represents the adoption of an overall ICM approach, essentially an umbrella program under which all other system improvements are made. In order to make this happen, two systems engineering and software efforts are required including the ICM and DSS

[13]Experience simulating a fully connected transportation system, September 1, 2012, http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/C932F344254A872185257EE600659DA1?OpenDocument&Query=Home, accessed August 2016.

software implementations. In order to progress with these, the next steps in the systems engineering process must be undertaken. The medium sized rectangle in Figure 24 is labelled Traffic Operations Systems to be consistent with the Caltrans nomenclature. Essentially this level of engineering represents the on-going ITS deployment in the corridor. Since there is already a complement of existing ITS, this rectangle represents expanding and upgrading ITS to meet additional ICM needs. Finally, the smaller rectangle includes two pilot projects, to demonstrate the effectiveness of Bus on Shoulder and Adaptive Ramp Metering. These can be designed and built at a relatively low cost, but must be deployed within the framework of ICM and TOS to be more effective.

6 COST AND BENEFITS OF DEPLOYMENT ALTERNATIVES

In this Section, three alternative approaches to deployment of the system recommended in Chapter 5 are discussed and compared. The system advances the seven key strategies, implemented and managed using an integrated and coordinated approach. The system will help CCTA achieve the key goals identified for the I-680 corridor and listed in Section 2. Each alternative discussed in this Section will meet these goals, albeit on a different time scale. A summary of these goals are as follows:

SYSTEM GOALS

"Through innovation, provide a resilient corridor that can sustain the peak mobility demands and meet socio-economic and environmental needs for today and the future."

The goals are anticipated to be achieved by strategic deployment of infrastructure and technology with an integrated management of all transportation assets in the I-680 corridor each optimized to maximize the throughput of persons and vehicles.

CCTA analyses using key performance measures in the corridor have shown significant differences in traffic flow, congestion, and safety along distinct segments can be expected within the corridor with system deployment. Therefore, the scope of deployment of the proposed alternatives could be tailored to mitigate the performance challenges within these segments of the corridor. For instance, significant congestion is notable in the northbound direction from just north of Crow Canyon Road to CA-242. There appears to be significant vehicular incidents in both the northbound and southbound directions of I-680 between CA-24 and CA-242. Finally, the flow regime fluctuates significantly between Post Mile 46 to Post Mile 57. Given today's funding constraints, implementing all solutions corridor wide from the start is not a practical deployment approach.

6.1 ALTERNATIVE 1: PILOTS ONLY

In this alternative, the two pilot projects shown in Figure 24 will be progressed as stand-alone pilot projects, with a Concept of Operations being done for each. The pilot project approach is to select a small segment of road where a high benefit is expected, and test the new technology to demonstrate its effectiveness to stakeholders and the public. The remainder of the seven identified component strategies and their sub-components developed by the stakeholder group will either continue if already started, or be placed on hold pending available funding.

Strengths of Alternative 1:

- Pilot projects are smaller, more affordable demonstrations of technology that if proven successful will set the foundation and build support for larger deployment.

- If two high-benefit locations are selected, this approach will deliver "the best bang for the buck" in the short term.

Weaknesses of Alternative 1:

- Pilot projects are smaller; however less efficient in the long run as the same amount of permitting and processes are required for a small technology project as a larger one. Larger projects achieve "economy of scale." As an example, a project to deploy 40 ramp meters does not cost twice as much as a project to deploy 20 ramp meters. The software and systems cost is the same for both projects.

- In the case of adaptive ramp metering, corridor wide solutions work the best due to the need to redistribute demand. Caltrans District 4 may not have "off the shelf" ARM software ready.

6.2 ALTERNATIVE 2: PILOTS AND ICM

This alternative is identical to Alternative 1, with the addition of building the ICM framework that is so essential to achieving the goals of Innovate 680. The goal is to reduce demand and provide convenient alternatives that will reduce the use of single occupancy vehicles or influence time of day when trips are made. The ICM will interface to BART parking garages to use smart parking technology to help travelers locate convenient affordable parking in real-time, provide first/last mile connectivity to and from transit stops, implement technology for innovative operational strategies (ICM, ATM, AAM) and adaptive ramp metering with DSRC connectivity for instance to bus on shoulder and serve as foundational infrastructure for future connected vehicles in the corridor.
Alternative 2 requires that a full Concept of Operations be prepared for all the ICM elements, including the technology and subsystems of the two pilot projects.

Strengths of Alternative 2:

- Alternative 2 maintains and delivers the strengths and benefits of Alternative 1.

- Alternative 2 maintains the focus on integration that is essential to the Innovate 680 program, so that progress continues on all of the seven component strategies rather than putting any "on the shelf."

- By progressing an "omnibus" ConOps for Innovate 680, additional projects will be closer to implementation should funding opportunities arise. Greater cost efficiency will be achieved in the long run by having one document instead of many.

Weaknesses of Alternative 2:

- An omnibus ConOps for Innovate 680 will require additional engineering funds early in the process. There will be some economy of scale in the ConOps for the Pilots will be included.
- An omnibus ConOps may be harder to get approved, in that there will simply be more elements requiring discussion and consensus building.

6.3 ALTERNATIVE 3: ICM INCLUDING ARM AND BOS

This alternative is identical to Alternative 2, except that the idea of doing pilot projects is not included, and the ARM and BOS elements are fully implemented in the Corridor. This does not necessarily mean that ARM and BOS will be operating the length of the Corridor. Implementation will still be based on selection of high benefit segments.

Strengths of Alternative 3:

- Alternative 3 will deliver a higher benefit initial "build" than the other alternatives, as more of the facility will be implemented.
- Alternative 3 involves less of a "gamble" with the public and local stakeholders, in that perceptions around a limited Pilot project will likely be a mix of positive and negative reaction. In Alternative 3, true buy-in will be created prior to the projects moving forward.

Weaknesses of Alternative 3:

- An omnibus ConOps for Innovate 680 will require additional engineering funds early in the process.
- The cost of full implementation of ARM and BOS may exceed available funding sources.

6.4 COST AND BENEFIT DISCUSSION

The benefits that will accrue and the cost involved in implementing any of the strategies to mitigate the challenges in the I-680 corridor (congestion, safety, environmental, etc.) depends on establishing measures of effectiveness (MOEs) which can depend on several metrics depending on the context, and the range or scope of deployments of the identified strategies as noted in the alternatives discussed above. No definitive cost benefit analysis can be provided for the I-680 corridor during this concept exploration phase. However, Table 3 below is provided for informational purposes to show the outcomes of implementing similar strategies at other locations.

Table 3: Benefit and Cost of Proposed Strategies[14]

Strategy	Approach	Benefit/Cost Ratio (N/A = Not Available)
Complete HOV/Express Lanes	Express lanes with dynamic tolling	6:1[15]
Cool Corridor Hot Spots	Express lanes with dynamic tolling	6:1[11]
	Collector-Distributor Road System	7.3:1[16]
Transportation Demand Management Strategies	Ride Share	3:1[17]
Increase Efficiency of Bus Service	Bus-on-shoulder	1.8:1
First/Last Mile Connectivity	Bus-on-shoulder	1.8:1
	Mobility-on-Demand	N/A
	SAV	N/A
	Smart Parking	N/A
Innovative Operational Strategies	Adaptive Ramp Metering (ARM)	15:1
	Integrated Corridor Management	10:1 to 25:1
	Traffic Operations Systems (ITS)	10:1 to 25:1
	Active Traffic Management (ATM)	7:1 to 62:1
	Connected Vehicles (CV)	6:1
	Speed Harmonization	88.6:1[18]
	Queue Warning Systems	N/A
	Dynamic Lane Management	N/A
	Decision Support Systems (DSS)	1.3:1 to 8.7:1
	Commercial Vehicle Operations	N/A
Corridor for the Future	Connected Vehicles (CV)	6:1
	Autonomous Vehicles	N/A

6.5 RECOMMENDED APPROACH

The recommended approach to Innovate 680 deployment has been determined jointly by the CCTA, their constituents and institutional stakeholders. The recommended approach and associated implementation plan is articulated in Section 7 of this report. The approach selected most closely fits the Alternative 2 described in Section 2; a combination of pilot projects for innovative new technology combined with more traditional traffic operations improvements all in an Integrated Corridor Management (ICM) context.

[14] Benefit/Cost Ratio resource:
ITS Knowledge Resource, http://www.itsbenefits.its.dot.gov/
FHWA, Transportation Systems Management and Operations Benefit-Cost Analysis Compendium
https://ops.fhwa.dot.gov/publications/fhwahop14032/index.htm#toc

[15] http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/FDC8084ED7FACBC485257CA70071C641?OpenDocument&Query=Home

[16] http://www.fdot.gov/planning/economicstimulus/swfia/costsbenefits-1.pdf

[17] http://onlinepubs.trb.org/Onlinepubs/trr/1989/1212/1212-011.pdf

[18] http://www.theconf.com/presentations/2017/Speed%20Harmonization.pdf

7 IMPLEMENTATION PLANNING

The Innovate 680 program will be implemented with a series of low cost traffic operations and ITS projects consistent with the seven strategies outlined in this report, as well as strategic capital improvements to the highway.

7.1 INNOVATE 680 PROJECT TRACKS

The Innovate 680 traffic operations projects will include innovative technology pilot projects, coordinated and integrated with traditional traffic operations improvements all in an Integrated Corridor Management (ICM) context. Figure 23 shows how the projects described in the seven strategies will be grouped into four project tracks for implementation.

- Track 1, Advanced Technologies, will commence with the completion of the systems engineering process and Concept of Operations for a complete upgrade of the Corridor TOS equipment and deployment of new equipment to support innovative emerging technologies. Several Pilot projects will be designed to demonstrate technological advances prior to corridor-wide implementation.

- Track 2, Bus-on-Shoulder, consists of a combination of operational improvements to prepare the shoulders for use by express buses, incident management workshops to address concerns related to first responders, training for bus operators and installation of electronics for connected vehicle applications and dynamic message signing. The two projects identified will be Pilot projects designed to demonstrate to the public and law enforcement personnel the techniques of shoulder utilization.

- Track 3, HOV/Express Lane Gap Closure and Cooling Hot Spots, will commence with a combination of further study of alternatives for creating continuous express lanes in the corridor, as well as reconfiguring the roadway to eliminate weaving at Hot spots in the Corridor.

- Track 4, Transit Improvements, aims at improving the efficiency of the bus service through increasing the capacities of the Park and Ride lots in the corridor, increasing shuttle services and school buses, and adding more buses.

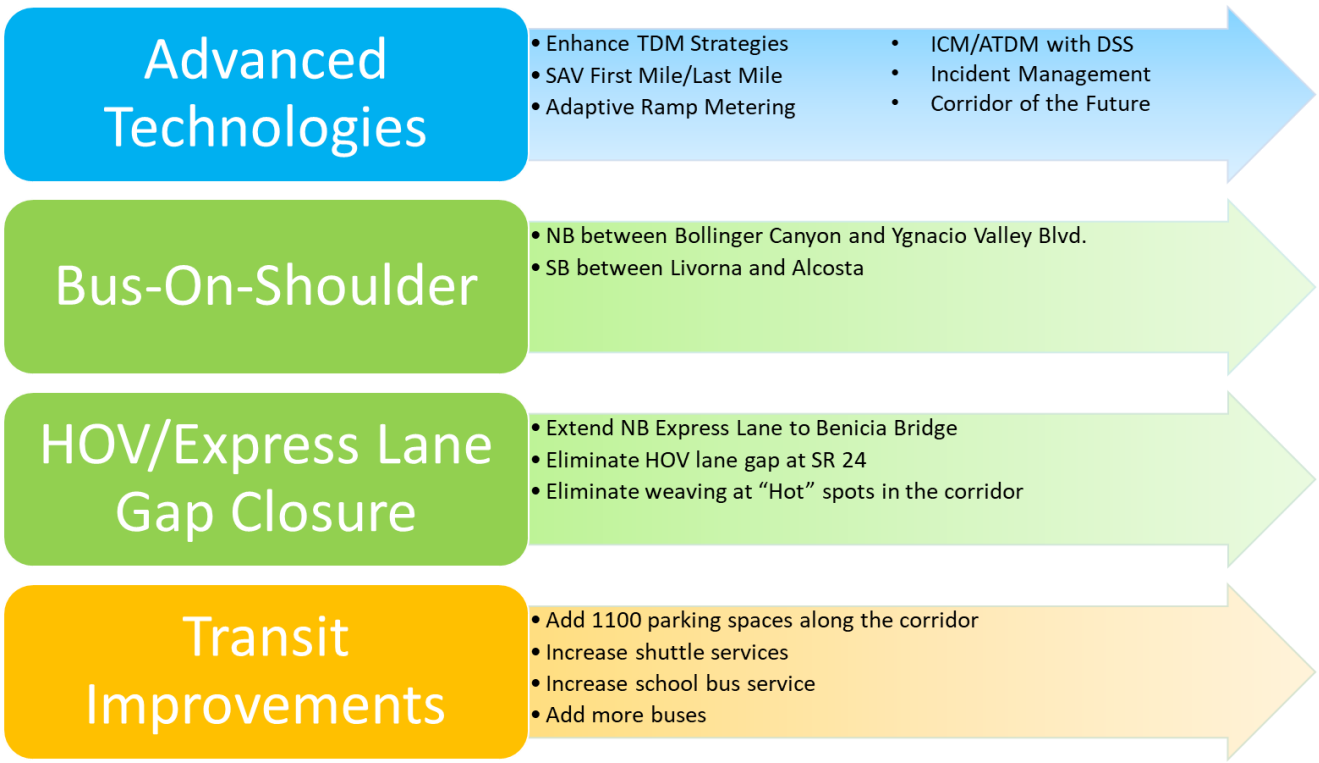

Figure 23: The Four Project Tracks of Innovate 680

7.2 IMPLEMENTATION PLAN FOR INNOVATE 680

A plan has been developed by CCTA for implementation of the four project tracks identified in Section 7.1. This plan will be conducted starting immediately in 2017 by several activities in parallel depicted in Figure 24. Applications for technology grants and funding for the systems will be sought while the Caltrans-required Concept of Operations is conducted based on furthering the design process started by this report.

Innovate 680 Outreach

The implementation plan will start with a series of outreach initiatives, consisting of making presentations to develop advocacy and receive feedback from corridor cites and the Regional Transportation Planning Committee (RTPC). Based on feedback and input from partners, the CCTA Transportation Strategic Plan will be amended to reflect the priorities of the four Innovate 680 Project Tracks. The partnership process will center around those identified partners, many of which participated in the creation of this report. The initial set of partners are shown in Figure 25.

Project Study Report-Project Development Support Documentation

All four project tracks require project development and coordination with Caltrans. Project Development requires CCTA to work with Caltrans and involved regional and local agencies to achieve consensus on the purpose-and-need, scope, and schedule of the Innovate 680 improvements. Once the project development strategies are identified and approved by Caltrans, projects will move into the Project Initiation Document (PID) stage. Standard ITS projects utilizing Caltrans approved TOS equipment may be streamlined through these requirements, as can Pilot Projects that are temporary in nature and do not have on-going environmental impacts.

A project development team (PDT) will be formed for each project track and address multiple projects within the track.

Figure 24: Partnering and Outreach Plan for Innovate 680

Concept of Operations

As described in Section 1, the Concept Exploration is required for ITS projects by Caltrans as part of their standardized Systems Engineering process. The concepts developed for Innovate 680 described in this report are part of the design of an overall Integrated Corridor Management (ICM) System. The next step in design is to complete the Concept of Operations required by the Caltrans guidelines referenced in Section 1 of this report.