
Prepared For
Contra Costa
Transportation Authority



# I-680 Transit Investment/Congestion Relief Options Study

## Final Report

Prepared by

DKS

In Association With
Parsons Transportation Group
CIrclepoint

December 9, 2015

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*Prepared for*

**Contra Costa Transportation Authority**

***By***

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**December 9, 2015**

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# GLOSSARY OF ACRONYMS

AGT – Automated Group Transit

ACE – Altamont Commuter Express

ACTC – Alameda County Transportation Commission

ATM – Active Traffic Management

BART – Bay Area Rapid Transit

CC – County Connection

CCTA – Contra Costa Transportation Authority

CSMP – Corridor System Management Plan

CTP – Countywide Comprehensive Transportation Plan

CV/AV – Connected Vehicle and Automated Vehicle

CSAV – Connected Shared-Use Autonomous Vehicle

DEIR – Draft Environment Impact Report

DMU – Diesel Multiple Unit

FAST – Fairfield and Suisun Transit

HOV – High Occupancy Vehicle

MTC – Metropolitan Transportation Commission

LAVTA – Livermore-Amador Valley Transit Authority

PAC – Policy Advisory Committee

PDA – Priority Development Area

RM2 – Regional Measure 2

ROW – Right of Way

RTPC – Regional Transportation Planning Committee

SFO - San Francisco International Airport

SOV – Single Occupant Vehicle

SWAT – Southwest Area Transportation Committee, the RTPC for Southwest Contra Costa County

TAC – Technical Advisory Committee

TEP – Transportation Expenditure Plan

TRANSPAC – Transportation Partnership and Cooperation, the RTPC for Central Contra Costa County

TVTC – Tri-Valley Transportation Council

# EXECUTIVE SUMMARY

This document provides a recommendation for transportation investments in the I-680 corridor that facilitate the use of transit for local and regional travel and address growing traffic congestion in the corridor. The study is a continuation of planning efforts in the corridor, including the I-680 Investment Options Analysis, prepared for the Contra Costa Transportation Authority (CCTA) in 2003. In 2004, voters approved Measure J, which will provide approximately $2.7 billion (Year-of-Expenditure dollars) for countywide and local transportation projects and programs through the year 2034. Measure J provided funding for some of the improvements recommended in the 2003 study, including new auxiliary lanes, express bus service, HOV lane extensions, and direct access ramps to the I-680 High-Occupancy-Vehicle (HOV) lanes. These investments are ongoing.

In addition, MTC is currently implementing a program to convert the HOV lanes on I-680 and other freeways in the Bay Region to Express Lanes. Express Lanes are specially designated HOV lanes that continue to offer toll-free travel for carpools, vanpools, motorcycles, buses and eligible clean-air vehicles, while also allowing solo drivers the option of paying to enter the HOV lane to avoid congestion, with tolls rising and falling with congestion levels. Tolls are collected electronically via the FasTrak® system, which is managed by MTC. The Express Lane project on I-680 from Livorna Road to Alcosta is currently under construction.

Population and employment in the corridor has fluctuated with the economy. Following the "Great Recession" of 2007, employment diminished, as did traffic. Currently, with the economic recovery in full swing, traffic in the corridor has increased significantly, far surpassing pre-recession levels. While the number of jobs and residents is nearly balanced in the Tri-Valley area, almost half of residents work outside of the area, and a growing number of people are commuting into the corridor for work. BART continues to attract new riders, but the demand for parking at the stations routinely exceeds capacity, and auto access to the BART stations is difficult as congestion continues to worsen along the I-680 corridor.

In 2012, the CCTA began to update its Countywide Comprehensive Transportation Plan (CTP). A draft of the 2014 CTP was issued in August 2014. An extensive public outreach process was conducted in the fall of 2014. That effort resulted in feedback from the public indicating a strong interest in improving transit service in the I-680 corridor. In addition, the Tri-Valley, Lamorinda, and Central County Action Plans all support congestion relief and improved transit options along I-680.

To develop the recommended corridor investment, this study reviewed the current and future transportation systems, land use and travel characteristics in the corridor. Several available transportation technologies were evaluated and screened to refine the options for the corridor. The top-priority investments were further evaluated, including an assessment of costs and transportation benefits. The final result was a recommended investment package for the corridor.

Throughout the process, the consulting team worked closely with CCTA staff, and a Policy Advisory Committee (PAC) and Technical Advisory Committee (TAC) were established for the

project. The Consulting team consisted of DKS Associates, Parsons Corporation and Circlepoint. The PAC included elected officials from:

- CCTA
- Contra Costa County Board of Supervisors
- County Connection
- BART
- TRANSPAC, TVTC, and SWAT (representatives from the Town of Danville, and the Cities of Walnut Creek, Lafayette, Pleasant Hill, San Ramon, and Dublin)

The TAC included representatives from:

- CCTA
- Alameda County Transportation Commission (ACTC)
- BART
- Bishop Ranch
- Caltrans
- County Connection
- TRANSPAC, TVTC, and SWAT (representatives from the Town of Danville, and the Cities of Walnut Creek, Lafayette, Martinez, Orinda, Pleasant Hill, Pleasanton, San Ramon, Walnut Creek, and Dublin)
- Contra Costa County Department of Conservation and Development
- Bike East Bay
- Livermore Amador Valley Transit Authority (LAVTA – Wheels)

## Initial Options Considered and Screening

The study identified five modal groups for analysis:

- Connected Vehicles/Automated Vehicles (CV/AV) and Related Infrastructure (2 variations)
- Bus Transit (3 variations)
- Light Rail (4 variations)
- Ultra-Light Rail (2 variations)
- Heavy Rail (5 variations)

Within each of the categories, various alignments and propulsion methods were assessed for a total of 16 preliminary options. These were scored and compared using the following criteria:

- Increase Person Throughput
- Attractiveness to New Users
- Enhance Connectivity
- Minimize Impact to Traffic Operations
- Minimize Right-of-way Requirements

- Community Acceptance
- Policy Consistency
- Minimize Construction Impacts
- Minimize Environmental Impacts
- Cost
- Markets

In addition, a rough cost estimate was developed for each option.

## Evaluation of the Top Priority Options

After the initial screening and consultation with the PAC and TAC, the top priority options were identified as:

- Connected Vehicles/Automated Vehicles (CV/AV) and Related Infrastructure
- Enhanced Bus
- Ultra-Light Rail
- Heavy Rail

At this level of analysis, the Light Rail mode was eliminated as an option and the other modes were refined. The potential communication equipment and related infrastructure needed for the CV/AV option was identified. For the enhanced bus option, potential locations for park-and-ride lots were identified and a service plan was developed to estimate the number of additional buses required. The alignments of the rail options were defined to allow for a more detailed cost estimate and to ensure that the routes were feasible.

The following evaluation criteria were used to compare the relative strengths and weaknesses of each option:

- Capital and Operating Costs
- Travel Time Impacts
- Potential Mode Shift
- Markets Served
- Connectivity
- Construction Impacts
- Potential Environmental Impacts
- Conflicts with Other Traffic
- Constructability Issues

All rail options were found to have capital and operating costs that would be infeasible to fund under a one-half cent extension of Measure J, although they would provide higher capacity and generally lower in-vehicle travel times than the enhanced bus option alone. The Enhanced Bus and CV/AV options had complementary strengths in reducing travel times while improving transit capacity in the corridor. These options were combined and expanded upon for the final evaluation.

## Recommended Investment Package

After careful consideration of a broad range of investment options for the I-680 corridor and with considerable input from the PAC and TAC, the DKS Team developed a recommendation for investment for the corridor that would: A) improve transit service, by extending service hours, expanding areas served, offer new services, and increasing operational capacity along the corridor; and B) improve freeway operations and reduce congestion on I-680. The recommended investment strategy would build on the progress made with previous investments in transit services in the corridor. It would also take advantage of the significant advancements in communications, vehicle automation and transportation system management that are changing how people will travel and interact with each other in the future.

A) **Improve Transit Service**: The recommended strategy for the I-680 corridor would improve transit service and capacity by providing additional local and express bus service, new park-and-ride facilities with shuttle service to BART, and provide operational benefits for buses by reconstructing segments of the I-680 shoulder and extending auxiliary lanes between ramps to allow buses to use these lanes to bypass traffic congestion in the general purpose lanes. Shared-use mobility elements would be incorporated into the transit-enhancement elements of the strategy. Existing and proposed park-and-ride facilities would serve as Smart Mobility Hubs with passenger information and amenities, secure bike parking, and access to bike sharing, car sharing, dynamic ridesharing, and demand-responsive transit services.

B) **Improve Freeway Operations:** The recommended investment strategy would implement a suite of advanced technologies and techniques known as Innovative Transportation Systems Management. This package includes support for connected and automated vehicles on I-680 using new communication technologies and high-visibility pavement markings. Active Traffic Management would be used to monitor traffic conditions, provide information to drivers and to connected vehicles, and improve efficiency through techniques such as adaptive ramp metering and dynamic lane use. Connected Shared Autonomous Vehicles would provide demand-responsive transportation between transit hubs, residences, and businesses using driverless electric vehicles operating on local streets.

The following fact sheets summarize the key features of the recommended strategy, which are grouped into four categories:

1. Enhanced Bus Service
2. Connected and Automated Vehicle Support on I-680
3. Active Traffic Management
4. Demand-Responsive Transit Service (using Connected Shared Autonomous Vehicles on local streets)

Implementation of the strategy would allow integration of transportation infrastructure, management, technologies, policies and operational efficiency and foster collaboration among agencies and across jurisdictions in the I-680 corridor.

## 1. Enhanced Bus Service (Walnut Creek to Dublin)

| | |
|---|---|
| **General Description** | This package of improvements would provide additional transit service in the corridor. This would include construction of new park-and-ride facilities with shuttle service to BART; addition of express, local and school buses services; and the addition of auxiliary lanes and reconstruction of shoulder lanes on I-680 (as needed) to allow buses to operate in the auxiliary lanes and shoulders to bypass congestion in the general purpose lanes. Buses could operate in the Express Lanes as well. |
| **Key Elements** | **Additional Park-and-Ride Lots with Smart Mobility Hubs** – Four new park-and-ride facilities would be constructed near I-680 between Walnut Creek and San Ramon. The facilities would accommodate a total of 1,100+ parking spaces, provide passenger amenities, and potentially incorporate car sharing, bike sharing, demand-responsive services and employer-based transportation.<br><br>**New Shuttle Service and Enhanced Local and Express Bus Service** – Six shuttle routes would provide direct service between park-and-ride lots and BART stations (2 from existing and 4 from new facilities). Current express and local service would be increased during the off-peak periods.<br><br>**Bus On Shoulder Operation (I-580 to SR-24)** – Shuttle and express buses would operate on I-680 in existing or expanded auxiliary lanes and in shoulder lanes to bypass traffic congestion in the general purpose lanes. Longer-haul buses could use the Express Lanes. Operating buses in the shoulder lanes would require a change in California Vehicle Code and a change in Caltrans policies.<br><br>**Increased School Bus Service** – The existing TRAFFIX Program supported by Measure J would be expanded and/or supplemented. TRAFFIX is a traffic congestion relief program operated jointly by the Town of Danville, City of San Ramon, Contra Costa County, and the San Ramon Valley Unified School District.<br><br>**Additional Transit Vehicles** – New vehicles would include buses needed for shuttle service, buses for expanded local and express service and school buses. |

## 2. Connected and Automated Vehicle Support (Benicia Bridge to SR-84)

| | |
|---|---|
| **General Description** | This package of improvements would facilitate Limited Self-Driving Automation (known as Level 3 automation), where the driver cedes full control of all safety-critical functions to the vehicle in almost all circumstances while on the freeway. Enhanced pavement markings and maintenance would provide improved visual guidance and reduced interference for automated driving functions. Transit vehicles, automobiles and their drivers would receive information about upcoming road and traffic conditions, via two-way vehicle-to-infrastructure communications along the corridor, with the goal of preventing incidents. The roadside equipment and connected vehicles would also provide information for managing the freeway. |
| **Key Elements** | **Vehicle-to-Infrastructure Communication** – Advanced radios and processors along the roadway would have capabilities to send and receive data to and from vehicles. This could include information on upcoming traffic conditions and lane closures.<br><br>**Fiber Optic Communication** – Devices along the roadway would be connected through a network and transmit data to a central location.<br><br>**High Visibility Pavement Markings –** Vehicles with automation capabilities use pavement markings for guidance and enhanced markings would improve accuracy.<br><br>**Increased Roadway Maintenance –** Maintaining excellent road conditions and removing debris would reduce interference for automated vehicles and transit vehicles using shoulder lanes.<br><br>**Transit Vehicle Assist and Automation** – Adding automated driving functions to transit vehicles would potentially reduce the width required for buses operating on the shoulder lanes. |

## 3. Active Traffic Management (Benicia Bridge to SR-84)

| | |
|---|---|
| **General Description** | This package of improvements would provide technology to collect data and communicate with drivers to maximize the efficiency of the roadway. These technologies would initially use a combination of roadside digital signs and in-vehicle messages, but eventually would fully transition to in-vehicle communication technologies as more vehicles are equipped. Adaptive ramp metering would be used to control the flow of vehicles entering I-680. Implementation of these technologies would involve a cooperative, multi-jurisdictional planning process throughout the corridor. |
| **Key Elements** | **Vehicle Detection and Surveillance** – A combination of sensors and cameras along the roadway would monitor vehicle speeds and provide real-time information on traffic flow and incidents to the traffic management center.<br>**Driver Information System** – Drivers would receive information on advisory speeds, notices on traffic conditions, queue warnings, lane closures and construction activities.<br>**Dynamic Lane Use Management** – Lane usage would be managed based on traffic data and inputs from the traffic management center. Drivers would be informed of lane closures in advance to allow lane changes and avoid rear-end collisions. For example, during construction or an incident, lane usage could be dynamically adjusted to maximize flow around the affected area.<br>**Adaptive Ramp Metering** – Traffic signals on ramps would dynamically control the rate vehicles enter the freeway based on real-time traffic conditions and historic data. The system could be integrated with adjacent arterial traffic signal operations to optimize the flow of the freeway while preventing backups to the adjoining roadways. Authorized transit, emergency and police vehicles would be able to receive an earlier green light or bypass ramp meters, in some cases.<br>**Integrated Information Management System** – A network of computer systems would process data from the roadway (and from connected vehicles) and allow management of the ramp meters and driver information systems. Roadside cameras would provide visual information to traffic management staff. Data from the management system could be shared with emergency/incident response teams. |

## 4. Demand-Responsive Transit Service (Connected Shared Autonomous Vehicles)

| | |
|---|---|
| **General Description** | Connected Shared Autonomous Vehicles (CSAVs) are self-driving (Level 4) electric vehicles designed to travel on local roadways at speeds less than 25 miles per hour. In the I-680 corridor, the vehicles would provide demand-responsive service between park-and-ride locations, residences and employers. The service would be requested using a computer, smart phone, or at consoles placed at park-and-ride mobility hub locations. |
| **Key Elements** | **CSAV Fleet and Operational Environment** – The electric shuttles would have a capacity of 12 passengers (6 seating and 6 standing) and would operate at speeds up to 25 mile per hour. The vehicles would be capable of operating on various local streets and in commercial areas.<br><br>**CSAV Hub/Docking Station** – The vehicles would drop off and pick up passengers at park-and-ride locations along the corridor. These areas would also serve as locations for battery charging and light maintenance/cleaning. Consoles would be placed at the hubs to enable people to request vehicles without using a smart phone.<br><br>**Sensor and Communications** – The vehicles would be capable of sensing their environment and navigating without human control. This would be accomplished through multiple sensors and communication technologies to ensure safe and accurate navigation.<br><br>**Advanced Control Systems** –Advanced control systems would interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage and prioritize safety.<br><br>**Innovative Business Models** – The technology and services offered by the vehicles would have the potential to create new business models for demand-driven transit with a mixture of fixed-route transit service for communities along the I-680 corridor and private-sector services such as Uber or Lyft. |

## Expected Cost and Effectiveness of the Investment Package

The estimated cost for the recommended investment option is between $215 and $230 million in capital construction and vehicle costs for the entire corridor. The annual operating and maintenance cost is estimated at $22.4 - $24.7 million. Roughly 85% of the capital costs would be in Contra Costa County but almost 95% of the operating costs.

As a result of the additional transit service, expected safety improvements from Connected and Automated Vehicles, better freeway management from the Active Traffic Management systems, travel time reductions are expected for single-occupant vehicles, vehicles using the HOV express lanes, and transit users. Depending on the trip length on I-680, the time savings vary from 5 to 7 minutes for single-occupant vehicles, 3 to 5 minutes for vehicles using the HOV express lanes and 12 to 18 minutes for transit users. The majority of the transit time savings were due to reduced wait and transfer times due to more frequent service.

Ridership for the proposed bus shuttles between the park-and-ride lots and BART was expected to be largely a function of the number of available parking spaces. It was estimated that 1,143 parking spaces would be provided at the park-and-ride lots to serve the traditional commute from within the corridor to outside the corridor. In addition, a number of riders would access transit through demand-responsive transit services, walking, biking and auto drop-off. Finally, reverse commenters would be able to access the corridor via transit. In total, the estimated transit ridership was approximately 2,300 to 2,800 daily boardings.

## Next Steps

Several steps remain before the recommended investment can be implemented. Funding must be secured, potentially as a part of an expenditure plan for a sales tax increase to supplement Measure J. The individual components will require further planning and design, including identification of specific locations for park-and-ride lots. In addition, many of the components will depend on integration of various systems and policies, further development of technology, and new regulations for their use.

# 1 INTRODUCTION

## Background

During public review of the Draft 2014 Countywide Transportation Plan (CTP), the Contra Costa Transportation Authority (CCTA) received strong support for improvements along the I-680 corridor between Walnut Creek and Dublin. Many stakeholders and participants voiced concern about the increasing levels of congestion on I-680, and the lack of viable transit options. The public outreach effort for the 2014 Countywide Transportation Plan (CTP) update included use of an innovative new web-based tool that allowed members of the public to submit their "bright ideas" for transportation improvements through the "keepcontracostamoving.net" website. To date, of the 350 bright ideas received through the website portal, 37 of them sought improvements along I-680. In addition, improvements to I-680 received strong support from members of the public across all public input mediums including paper surveys, emails and the in-person public workshops held in Walnut Creek and Lafayette. To be responsive to the comments received, the CCTA Board directed Authority staff to initiate a study of transit options and other congestion-reduction measures along the I-680 corridor.

In March of 2015, the I-680 Transit Investment/Congestion Relief Options Study was initiated under the direction of a Policy Advisory Committee (PAC) consisting of elected officials from local jurisdictions in the corridor and BART. The primary purpose of the study was to define and evaluate potential transportation investment options that could address the needs of the I-680 Corridor in the general area of the I-680 freeway from the Benicia-Martinez Bridge to SR-84 with a focus on potential transit service improvement and other congestion-reduction options between Walnut Creek and Dublin. The study area corridor is identified in **Figure 1**. The ultimate goal was to identify specific projects that might be considered for inclusion in a Transportation Expenditure Plan (TEP) that the Authority could develop for a potential Sales Tax Measure.

## Previous Studies

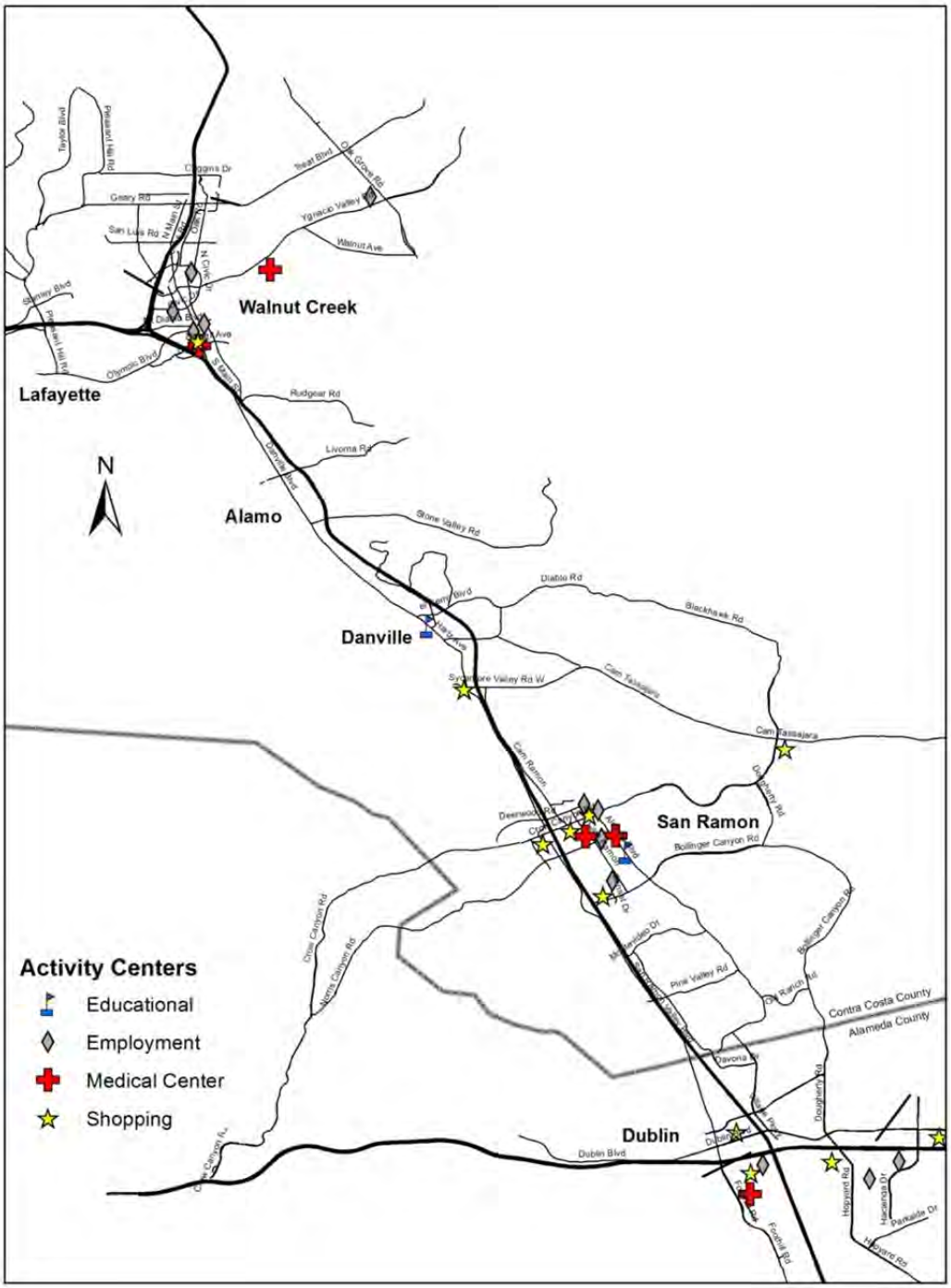
In 2003, the Authority funded the I-680 Investment Options Analysis. This study involved the qualitative analysis of a number of potential investment options, including BART, Light Rail, busways, Express Bus, and Express lanes. In response to community concerns, the options did not include the addition of mixed-flow lanes on I-680, or the construction of facilities along the Iron Horse Trail. The cost of this study was $140,000 (in 2002 dollars).

Prior to the 2003 study, the Authority conducted a corridor analysis of I-680 in the early 1990's. In parallel, Caltrans developed a series of studies for the corridor, including the I-680 Corridor Concept Report, published in 1985 and again in 2002. The latest one of these Caltrans studies was completed in May 2015 and was called the Corridor System Management Plan (CSMP). The CSMP examined programmed projects that include additional express bus service in the I-680 corridor, but BART and other rail services are not included in the analysis.

Another study along the corridor was the I-680 HOV/Express Bus Access Study. Completed in June 2010 using Regional Measure (RM) 2 funding, this study examined ways of providing direct

connector ramps from the I-680 HOV lanes into the Walnut Creek and Pleasant Hill BART stations.

**Figure 1: Primary I-680 Study Area**



# 2 CORRIDOR TRANSPORTATION CHARACTERISTICS

An overview of the geographic constraints of the Study Area is helpful to the discussion of the transportation system between Central Contra Costa and the Dublin/Pleasanton area in Alameda County. The developed area between Walnut Creek and Dublin/Pleasanton has evolved linearly, with large ridges of hills on either side of a valley that begins in the Alamo area and widens at the Alameda County line. The San Ramon Valley can be generally described as about two to three miles wide. The geography of the area has limited the number of east-west corridors to connect this area with the rest of the Bay Area resulting in the primary transportation routes being north-south.

The primary growth in this area has been post 1970, as Bay Area growth reached this area and as the I-680 freeway was opened. During the past twenty years, a considerable number of new employers have also located in this area, especially in the San Ramon/Bishop Ranch and Dublin/Pleasanton area. The suburban character of the study area, coupled with good freeway access and very little transit service, has resulted in most travelers choosing to drive to various destinations, whether the trip begins or ends in the San Ramon Valley, or just travels through the corridor.

## Roadway network

### I-680 Freeway

The corridor's main transportation facility is I-680, which runs north-south through the study area and is the major freeway connection between Contra Costa County and Santa Clara County. Along the I-680 corridor there are four freeway-to-freeway interchanges: SR-4, SR-242, SR-24, and I-580 (in Alameda County).

Other interchanges on I-680 are generally spaced at one to two mile intervals. Interchanges are located (from north to south) at Marina Vista/ Waterfront Road, Pacheco Boulevard, Concord Avenue, Willow Pass Road, Monument Boulevard, Contra Costa Boulevard, Treat Boulevard, San Luis Road/North Main Street, Ygnacio Valley Road, Olympic Boulevard, South Main Street, Rudgear Road, Livorna Road, Stone Valley Road, El Pintado Road, El Cerro Boulevard, Diablo Road, Sycamore Valley Road, Crow Canyon Road, Bollinger Canyon Road, San Ramon Valley Road/Alcosta Boulevard, Dublin Boulevard, Stoneridge Drive, Bernal Avenue, Sunol Avenue, Koopman Road/Pleasanton Sunol Road, and SR-84. Most interchanges have full access available to and from northbound and southbound I-680 traffic, except for Pacheco Boulevard, Contra Costa Boulevard, El Pintado Road (which coupled with nearby El Cerro Boulevard offers full access to I-680), and Koopman Road/Pleasanton Sunol Road . In 2013 auxiliary lanes were added between the Sycamore Valley Road and Crow Canyon Road interchanges.

**Table 1** provides a summary of characteristics of the I-680 freeway broken down into 8 segments between Walnut Creek and Pleasanton. The freeway varies from 6 to 12 lanes with a paved median. There are three northbound HOV segments as listed below:

- Alcosta Boulevard to Livorna Road
- SR-242 to Marina Vista Boulevard
- At the Benicia-Martinez Bridge toll plaza

There are two southbound HOV segments as listed below:

- Marina Vista Boulevard to Treat Boulevard
- Rudgear Road to Alcosta Boulevard

The hours of HOV-only operation are 5 AM to 9 AM, and from 3 PM to 7 PM in both directions. Only 2+ HOVs[1], very low-emission vehicles, and motorcycles are allowed to use the HOV lane during the hours of operation. There are no direct access ramps to or from the HOV lanes; all HOV lane traffic must enter from a mixed-flow lane.

[1] The HOV lane on the Benicia-Martinez Bridge requires 3 or more occupants per vehicle.

**Table 1: Characteristics of the I-680 Freeway**

| Location Description | Stoneridge Dr to I-580 | I-580 to Alcosta Blvd | Alcosta Blvd to Crow Canyon Rd | Crow Canyon Rd to El Pintado Rd | El Pintado Rd to Rudgear Rd | Rudgear Rd to SR-24 | SR-24 to N. Main St | N. Main St to SR-242 | SR-242 to SR-4 | SR-4 to Benicia-Martinez Bridge |
|---|---|---|---|---|---|---|---|---|---|---|
| General Purpose Lanes | 7-10 | 6-11 | 8-10 | 8-10 | 7-8 | 8-11 | 7-10 | 9-12 | 8-11 | 7-11 |
| Lane Miles | 8.0 | 15.6 | 37.9 | 31.9 | 33.4 | 17.2 | 9.4 | 35.4 | 23.2 | 38.0 |
| Centerline Miles | 0.9 | 1.7 | 4.6 | 3.9 | 4.2 | 1.7 | 1.1 | 3.2 | 2.7 | 4.3 |
| Median Width (Paved) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| HOV Lanes | 0 | 1 | 2 | 2 | 2 | 0 | 0 | 1 | 2 | 2 |
| HOV Characteristics | N/A | 2 or more persons per vehicle | 2 or more persons per vehicle | 2 or more persons per vehicle | 2 or more persons per vehicle | N/A | N/A | 2 or more persons per vehicle | 2 or more persons per vehicle | 2 or more persons per vehicle / 3 or more persons per vehicle at toll plaza |
| Auxiliary Lanes | 65% | 61% | 24% | 17% | 9% | 24% | 26% | 23% | 63% | 28% |
| Current ROW | 67 - 95 Ft. | 85 - 110 Ft. | 73 - 75 Ft. | 82 - 90 Ft. | 81 - 86 Ft. | 91 - 91 Ft. | 81 - 150 Ft. | 92 - 117 Ft. | 92 – 150 ft. | 67 – 95 ft. |

Source: Contra Costa County I-680 Corridor System Management Plan CSMP), August 15, 2014.

## Arterial Roadways

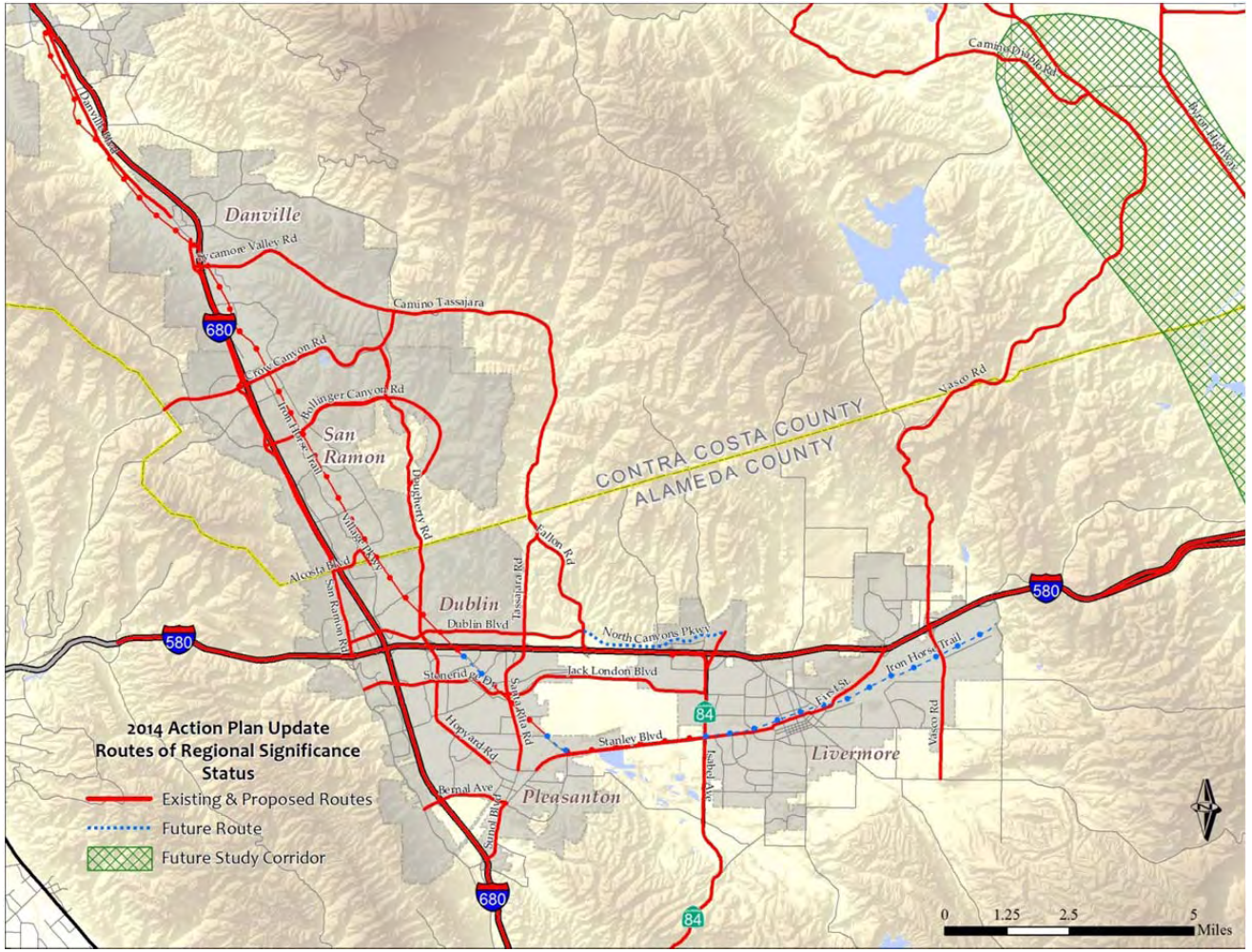
The major arterial routes that run north-south (parallel to I-680) in the core portions of the study area (between Walnut Creek and Dublin) are listed below. Routes of Regional Significance are identified, as defined in the SWAT and TVTC Action Plans for Routes of Regional Significance (see **Figure 2**).

- Pacheco Boulevard, Contra Costa Boulevard, N. Main Street, S. Main Street, Danville Boulevard, Hartz Avenue, San Ramon Valley Boulevard, and San Ramon Road run parallel to I-680 from Martinez to Dublin and vary from two to six lanes wide. These roadways are designated as a Routes of Regional Significance. The land use along this corridor also varies greatly.
- Alcosta Boulevard crosses I-680 at the south end of the study corridor and then runs parallel to I-680 through San Ramon. The roadway is a divided arterial roadway with two lanes in each direction. This roadway is designated as a Route of Regional Significance.
- Camino Ramon is a local collector roadway that parallels I-680 on the east side. It connects with Sycamore Valley Road and Fostoria Way.
- Dougherty Road is designed to serve a developing area of San Ramon. This roadway is designated as a Route of Regional Significance.

Other major cross-streets in the study area include:

- Bollinger Canyon Road runs between Crow Canyon Road and Alcosta Boulevard in San Ramon. The roadway is generally two lanes in each direction, although the central segment between San Ramon Valley Boulevard and Alcosta Boulevard has three lanes in each direction. This roadway is designated as a Route of Regional Significance.
- Crow Canyon Road connects northern San Ramon and southern Danville (Blackhawk area) to I-580 in Castro Valley. The roadway is generally two lanes in each direction west of Bollinger Canyon Road, where it widens to six or eight lanes until it reaches Alcosta Boulevard, and narrows again to four lanes. This roadway is designated as a Route of Regional Significance.
- Sycamore Valley Road connects Camino Tassajara/Tassajara Road with San Ramon Valley Boulevard. This roadway is a four-lane divided arterial roadway and is designated as a Route of Regional Significance.
- Camino Tassajara – a four-lane facility that connects Danville with the Dougherty Valley. The roadway is four lanes total east of Sycamore Valley Road, and two lanes between Sycamore Valley Road and Diablo Road. This roadway is designated as a Route of Regional Significance.
- Diablo Road – a two-lane local Danville roadway that runs from Hartz Avenue to Stone Valley Road.
- El Cerro Boulevard – a local Danville roadway that connects with Danville Boulevard and Diablo Road.

**Figure 2: Tri-Valley Routes of Regional Significance**




Source: Tri-Valley Transportation Plan and Action Plan for Routes of Regional Significance, Tri-Valley Transportation Council, 2014

- El Pintado Road – a local Danville roadway that connects with El Cerro Boulevard and La Gonda Way.
- Stone Valley Road – a two lane roadway that runs between Danville Boulevard and Diablo Road.
- Ygnacio Valley Road – a six-lane facility that runs between I-680 in Walnut Creek and Clayton Road in Concord.
- Treat Boulevard – a six-lane facility that runs between I-680 in Walnut Creek and Clayton Road in Concord.

### Planned Roadway Improvements

There are plans for major capital improvements at the I-680 and SR-4 freeway interchange. The improvements include the following: adding a third lane on SR-4 through the interchange, eliminating the weaving sections on SR-4 by adding two direct connectors, increasing the radius of the two remaining loops, and ultimately constructing an HOV connector ramp from westbound SR-4 to southbound I-680.

The I-680 Southbound HOV Gap Closure Project will provide continuity in the HOV system southbound through the SR-24 interchange. Funding has been secured for this project, but the existing gap northbound in this same location will be more expensive and funding is not available at this time. The southbound project will encourage HOV lane use by carpoolers and transit riders.

MTC is currently implementing a program to convert the HOV lanes on I-680 and other freeways in the Bay Region to Express Lanes. Express Lanes are specially designated HOV lanes that continue to offer toll-free travel for carpools, vanpools, motorcycles, buses and eligible clean-air vehicles, while also allowing solo drivers the choice to pay to enter the HOV lane to avoid congestion, with tolls rising and falling with congestion levels. Tolls are collected electronically via the FasTrak® system, which is managed by MTC. The Express Lane project on I-680 from Livorna Road to Alcosta is currently under construction

Studies are currently underway to evaluate the feasibility of constructing direct access ramps from the HOV lanes on I-680 into San Ramon. The following two scenarios are under evaluation:

- Rebuild the Norris Canyon Road overpass to include direct HOV on/off ramps for both directions of I-680. This scenario would provide access to both the east and west sides of I-680.
- Build new direct HOV on/off ramps to a new overpass structure at Executive Parkway for both directions of I-680. This scenario would provide access to only the east side of I-680.

The Central County Action Plan identifies a few additional proposed improvements. Along I-680, the Plan identifies 1) extending the HOV lane northbound from N. Main Street to SR-242 (Funded) and 2) modifications to the I-680/Marina Vista interchange (under construction). The Action Plan also lists capacity improvements on SR-4 between I-680 and Bailey Road including eastbound HOV lane extension (being studied).

The Tri-Valley Transportation Plan and Action Plan also identify a few additional proposed improvements. Along I-680, the Plan identifies 1) widening the I-680/I-580 interchange in each direction for HOV/express lanes, and 2) adding northbound and southbound HOV/express lanes between SR-84 and Alcosta Road, both of which have been planned but are not funded yet.

The I-680 Corridor System Management Plan, completed by Caltrans in 2015 examined several short, medium and long-term scenarios for transportation improvement projects in the corridor. Based on the analysis, the report recommended that freeway detection be expanded in the corridor. The extension of the Express Lanes to Livorna Road and the construction of the Crow Canyon Road/Sycamore Valley Road auxiliary lanes were expected to produce significant travel time savings on both the freeway facility and on local arterials in the short term, but congestion would likely return in the future and be greater than it is today without additional improvements. Ramp metering (with expansion of ramps to prevent backups) and additional auxiliary lanes were found to be effective (with a high benefit-to-cost ratio) in reducing vehicle delay. A reduction in vehicle miles traveled, through robust implementation of bicycle and pedestrian improvements, was shown to reduce congestion on arterial streets, with a modest impact on I-680. The analysis also showed how improved incident management, with faster lane clearance, could significantly reduce delay.

## Transit Service

There are a variety of transit services offered within close proximity to the I-680 corridor. There are two rail transit providers: Bay Area Rapid Transit (BART) and Altamont Corridor Express (ACE). The bus service providers include: County Connection, Wheels, Tri Delta Transit, Fairfield & Suisun Transit (FAST), and Soltrans. The rail and bus service providers will be discussed in this section in addition to the park-and-ride lots that supplement transit service.

### Rail Service

Bay Area Rapid Transit (BART) connects San Francisco, San Mateo, Alameda, and Contra Costa counties with passenger rail. There is currently no BART line that provides service south of Walnut Creek parallel to I-680; but there are BART stations in Concord, Pleasant Hill, and Walnut Creek that connect to Oakland, San Francisco, San Francisco International Airport (SFO) and Millbrae. At the south end of the corridor, the Dublin line has its eastern terminus at the Dublin/Pleasanton station. The line follows the I-580 corridor, with a station west of I-680 (West Dublin/Pleasanton), serves Castro Valley, connects to the Fremont line at Bay Fair and continues to San Leandro, Oakland and San Francisco before terminating in Daly City. A connection to Santa Clara County on the Fremont line is under construction.

Altamont Corridor Express (ACE) is a commuter rail service that provides service between Stockton and San Jose. The Pleasanton Station is about 5 miles south along I-680 past the I-580 freeway interchange.

## Fixed-Route Bus Services

County Connection is the main transit service provider through the corridor. Bus routes connect Martinez, Clayton, Concord, Pleasant Hill, Walnut Creek, Lafayette, Orinda, Moraga, Danville, San Ramon, Dublin, and Pleasanton, as well as many points in between.

Wheels is the bus service provider to Tri-Valley, operated by the Livermore Amador Valley Transit Authority (LAVTA). Wheels provides several bus services that connect to the Dublin/Pleasanton BART station near the freeway interchange of I-680 and I-580. Specifically, Route 70x connects the Pleasant Hill, Walnut Creek, and Dublin/Pleasanton BART stations via I-680. Route 70xv connects the Pleasant Hill, Walnut Creek, Dublin/Pleasanton, Dublin/Pleasanton, and West Dublin BART stations via I-680.

**Table 2** shows the Express Bus routes that travel along the I-680 corridor provided by the County Connection (CC) and Wheels.

**Table 2: Express Transit Service in the I-680 Corridor**

| Route (Provider) | Route Name | Peak Period Frequency | Major Stops |
|---|---|---|---|
| 92X (CC) | Ace Express | Three AM/PM buses | Pleasanton Train Station (ACE), Bishop Ranch, San Ramon Transit Center |
| 95X (CC) | San Ramon Express | 40 min | San Ramon Transit Center to Walnut Creek BART |
| 96X (CC) | Bishop Ranch Express, North | 10 min | Walnut Creek BART to Bishop Ranch |
| 97X (CC) | Bishop Ranch Express, South | 30 min | Dublin/Pleasanton BART to Bishop Ranch |
| 98X (CC) | Martinez/Walnut Creek Express | 30 min / 60 min | Amtrak, Concord, Walnut Creek BART |
| 70x (Wheels) | Pleasant Hill BART/Dublin Pleasanton BART | 30 min | Pleasant Hill BART , Walnut Creek BART, Dublin/Pleasanton BART |
| 70xv (Wheels) | Pleasant Hill BART/Dublin Pleasanton BART | Single AM/PM bus | Pleasant Hill BART , Walnut Creek BART, Dublin/Pleasanton BART, West Dublin BART |

Source: http://www.ccta.org/Country Connection.html , http://wheelsbus.com/index.aspx?page=245

Fairfield & Suisun Transit (FAST) provides a bus route between Vacaville and Walnut Creek (Route 40) that operates during the AM and PM peak periods during weekdays.

Soltrans provides two routes (routes 78 and 80s) that link Vallejo and the Walnut Creek BART station. These routes provide service during both the weekdays and weekend.

Tri Delta Transit provides Route 200, which connects the Pittsburg/Bay Point BART station and Martinez during the weekdays. Additionally, Route 201 connects the Pittsburg/Bay Point and Concord BART stations during the weekdays.

In addition to these transit operators, some of the large employers in the region provide shuttle services for their employees to/from BART, including Chevron and AT&T.

### Park-and-Ride

BART stations in Contra Costa County have park-and-ride lots that are used for commuters who use the BART service. Additionally, there are park-and-ride lots that are not affiliated with BART which are summarized in **Table 3**.

### School Service

School service is provided in the San Ramon Valley through the TRAFFIX program. Service began in 2009, and includes a fleet of buses that operate on fixed routes with defined stops. The buses are dedicated to school service and are not shared with the general public. The program is funded through Measure J, which will provide $40 million over 25 years. The program also charges a nominal fee per student on an annual basis.

As of 2012, TRAFFIX served 11 schools, including elementary, middle and high schools, and some schools have multiple routes. The pick-up and drop-off times and locations are coordinated with the individual schools. The total number of students served is approximately 1600 to 1800.

**Table 3: Park-and-Ride Lots not affiliated with BART**

| Park-and-Ride Name | Location | City | Highway | Number of Spaces | Existing Transit Service |
|---|---|---|---|---|---|
| Pacheco Transit Hub | Pacheco Boulevard @ Blum Road north of SR-4 | Martinez | 4 | 110 | Yes |
| Martinez | Alhambra Road & Franklin Canyon | Martinez | 680 | 24 | Yes (on street) |
| Concord | East of SR-242 / South of Willow Pass Road / West of Market Street | Concord | 242 | 45 | No |
| Mitchell | Mitchell Drive between Oak Grove Road & N Wiget Lane | Walnut Creek | 680 | 92 | Yes (on street) |
| Rudgear | SE Quad I-680 / Rudgear Road | Walnut Creek | 680 | 64 | No |
| Danville | Sycamore Valley Road & Camino Ramon | Danville | 680 | 230 | Yes |
| Bollinger | SW Quad I-680 / Bollinger Canyon Road | San Ramon | 680 | 108 | Yes (on street) |
| San Ramon | Camino Ramon & Executive Parkway | San Ramon | 680 | 55 | Yes |
| Pleasanton | Johnson Drive & Stoneridge Drive | Pleasanton | 680 | 83 | No |
| | | | Total Spaces | 811 | |

Source: Contra Costa County I-680 Corridor System Management Plan (CSMP), August 15, 2014.

## Planned Transit Improvements

The **2015 Tri-Valley Transportation Plan and Action Plan** recommends the following public transit improvements: enhanced ACE commuter service; additional park-and-ride lots; additional express bus service in heavily traveled corridors; additional local bus service to new development areas; reoriented local bus service to serve BART and park-and-ride lots, and decreased headways on existing routes. Future public transit projects and improvements will be guided with input from representatives of LAVTA, County Connection, ACE, and BART. The planning and coordination for Tri-Valley transit service should also be guided by an Alameda Countywide Transit Plan, now under development by the Alameda CTC, and the Countywide Transportation Plan being developed by CCTA.

**BART**. The San Francisco Bay Area Rapid Transit District is preparing a project-level Draft Environmental Impact Report (DEIR) for a BART-to-Livermore Extension Project. The proposed project is being developed in partnership with the City of Livermore. It consists of a 4.8-mile extension along I-580, using traditional electric BART trains, diesel-multiple-unit trains, or express bus service, to a station in the vicinity of the Isabel Avenue/I-580 Interchange and incorporating a bus-to-BART transfer opportunity. It also includes express bus services linking inter-regional rail service at the Vasco Road ACE Station, Priority Development Areas (PDAs) in Livermore, and proposed off-site parking facilities. Limited parking would also be provided at the Isabel Avenue/I-580 BART station.

**ACE Commuter Service.** The ACE commuter service, which began service through the Tri-Valley in 1998, provides peak-hour commuter train service between the Central Valley and Santa Clara County. The ACEforward plan would include operational improvements that would enable the system to expand service from four round trips per day to six between Stockton and San Jose and extending new rail service to downtown Modesto and Merced.

**Park-and-Ride Lots.** The Plan recommends the SMART parking program at BART stations and park-and-ride lots along I-580. This program is envisioned to have real-time electronic signs along I-580 that would inform motorists of the parking conditions at BART stations and park-and-ride lots, and coordinate the access to parking with LAVTA buses. Addition of new park-and-ride lots is also recommended in the Plan. These would be served primarily by public bus routes and shuttles, and could also serve as staging locations for carpools, bicycle storage and pedestrian access to each of these modes.

**County Connection.** The Plan calls for an improvement in on-time performance of buses and service changes to reflect an increase in development in San Ramon's Bishop Ranch Business Park. In the long-term, new service plans will be created to take advantage of future roadway improvements, including potential HOV direct access ramps installed at a location to be determined along I-680 near San Ramon's city center. Midday service may also be considered as a strategy to increase transit access in this area.

**LAVTA/Wheels.** Under the Plan, LAVTA would continue to expand and enhance public bus service within their service area. Current service priorities and goals include:

1. Increase frequency and reduce headways throughout the Tri-Valley area.
2. Extend service to underserved and newly developed areas.
3. Increase and/or improve regional connectivity with other transit operators and with other modes of transportation.
4. Solidify Rapid service in the Tri-Valley.

CCTA has also initiated an Express Bus Study to develop recommendations for improving express bus service in the I-680 corridor. The study will recommend short-term bus capital improvements as well as long-term investment strategies.

## Travel Characteristics

Analysis of household employment data showed that the number of employed residents was roughly equivalent to the number of jobs. However, approximately half of the employed residents commute outside of the area for work. Future trends indicate that population will continue to grow; however, employment is expected to grow faster than population (27 percent vs. 15 percent). This would indicate an increase in commute trips into the corridor.

In terms of mode share, the majority of work trips in the corridor are drive-alone, with about 6 to 8 percent of commuters using transit. Commuters living in Walnut Creek used transit at a higher rate, approximately 13.6 percent. BART attracted most of the transit trips: between 55 and 87 percent. In addition, approximately 6 to 9 percent of commuters carpooled.

### I-680 Traffic Volumes and Delay

Peak hour traffic volumes for the years 2000 and 2012 are shown in **Table 4** for various points along I-680. Most of the segments increased in volume during this time, with substantial increases in the northern and southern portions of the corridor (near Treat Blvd. and the Alameda County Line). Volumes were typically the highest in the Walnut Creek area near Treat Boulevard and lowest south of I-580 near Stoneridge Drive. The peak volumes were directional in the northern part of the corridor, with higher southbound volumes in the morning and higher northbound volumes in the evening. The other segments were not highly directional, with similar volumes in the northbound and southbound directions in the a.m. and p.m. peak periods.

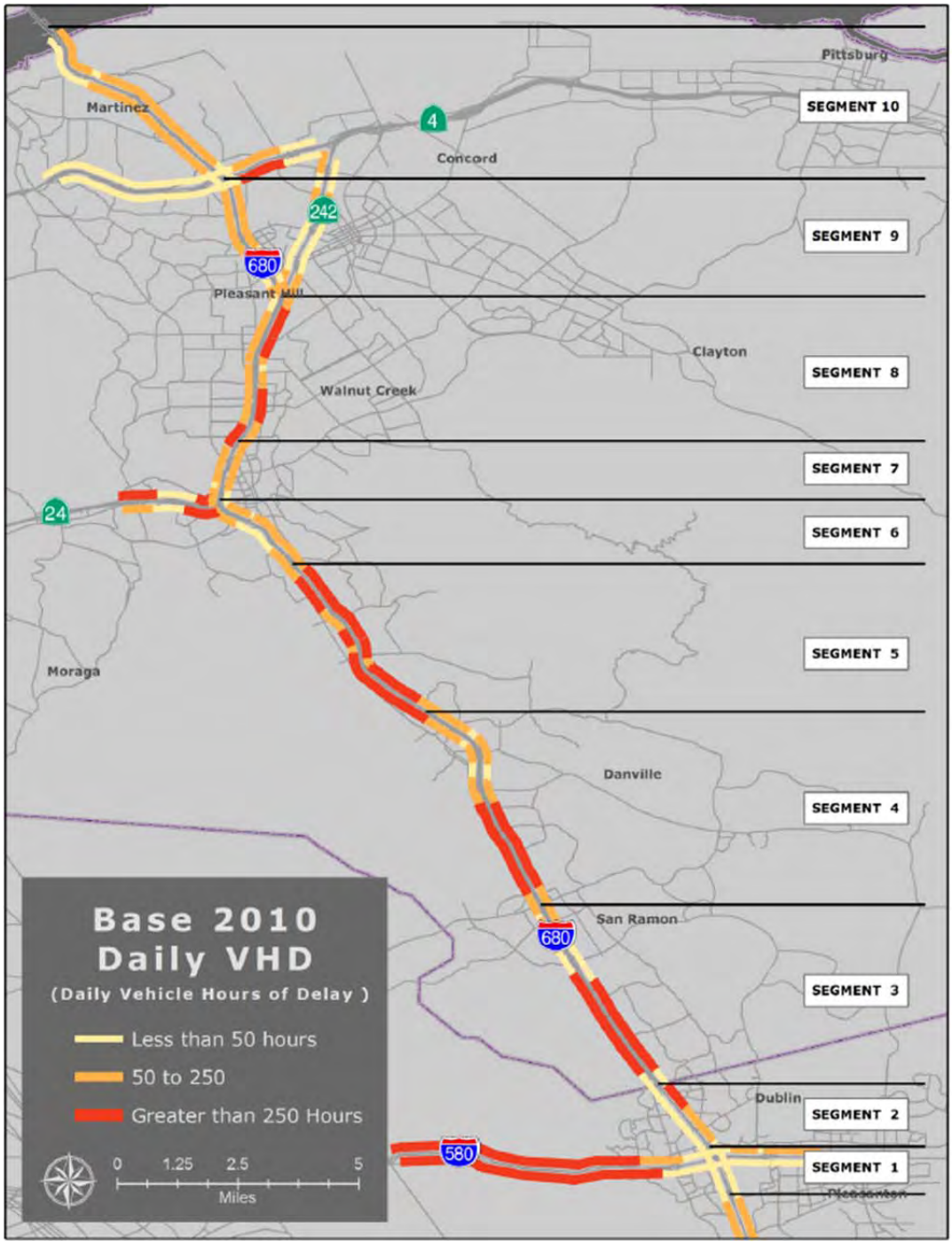
**Table 4: Traffic Volumes on I-680**

| Location | Peak Hour | 2000 Count | 2012 Count | % Increase |
|---|---|---|---|---|
| AM Northbound | | | | |
| Treat Blvd | 8:00-9:00 | 6,620 | 7,481 | 13.0% |
| Livorna Rd | 7:00-8:00 | 6,319 | 6,678 | 5.7% |
| Sycamore Valley Rd | 7:00-8:00 | 5,911 | 5,967 | 0.9% |
| Bollinger Canyon Rd | 8:00-9:00 | 5,758 | 6,238 | 8.3% |
| Alameda Co Line | 8:00-9:00 | 4,891 | 5,956 | 21.8% |
| Stoneridge Dr | 8:00-9:00 | N/A | 5,020 | -- |
| PM Northbound | | | | |
| Treat Blvd | 17:00-18:00 | 8,291 | 10,500 | 26.6% |
| Livorna Rd | 17:00-18:00 | 6,610 | 6,800 | 2.9% |
| Sycamore Valley Rd | 17:00-18:00 | 7,361 | 6,229 | -15.4% |
| Bollinger Canyon Rd | 17:00-18:00 | 6,268 | 6,358 | 1.4% |
| Alameda Co Line | 17:00-18:00 | 5,420 | 7,108 | 31.1% |
| Stoneridge Dr | 17:00-18:00 | N/A | 5,316 | -- |
| AM Southbound | | | | |
| Treat Blvd | 7:00-8:00 | 6,382 | 10,706 | 67.8% |
| Livorna Rd | 8:00-9:00 | 4,981 | 6,284 | 26.2% |
| Sycamore Valley Rd | 7:00-8:00 | 6,225 | 6,778 | 8.9% |
| Bollinger Canyon Rd | 8:00-9:00 | 5,460 | 6,469 | 18.5% |
| Alameda Co Line | 8:00-9:00 | 4,755 | 7,670 | 61.3% |
| Stoneridge Dr | 8:00-9:00 | N/A | 4,781 | -- |
| PM Southbound | | | | |
| Treat Blvd | 17:00-18:00 | 6,525 | 8,937 | 37.0% |
| Livorna Rd | 17:00-18:00 | 4,292 | 6,661 | 55.2% |
| Sycamore Valley Rd | 17:00-18:00 | 4,368 | 5,771 | 32.1% |
| Bollinger Canyon Rd | 17:00-18:00 | 5,911 | 6,766 | 14.5% |
| Alameda Co Line | 17:00-18:00 | 4,548 | 6,603 | 45.2% |
| Stoneridge Dr | 17:00-18:00 | N/A | 5,107 | -- |

*Source: Counts provided by Contra Costa Transportation Authority;*
*Count sources include Caltrans, MTC (I-680 Express Lanes Study). N/A= Not Available*

The delay map included in the 2015 Caltrans Corridor System Management Plan is shown in **Figure 3**. With the continued growth in the Bay area, including the migration of population and employment to outlying areas, the demand on I-680 is expected to increase steadily. Forecasts prepared as part of the *Central, East, Southwest Arterial and Freeway Ramp Metering Study* indicate a significant worsening of conditions in this segment, with congestion and queuing occurring for several hours at several bottleneck locations.

**Figure 3: Freeway Delay in the I-680 Corridor**




*Source: Interstate 680 Contra Costa Corridor System Management Plan (Caltrans 2015)*

## Transit Ridership

Transit ridership in the study area varies depending on the level of service and the locations served. According to data from March 2015, the average daily boardings for the County Connection express routes in the study area are as follows:

- Route 92X (ACE Express - Mitchell Drive Park-and-Ride to ACE Train Station): 204
- Route 95X (San Ramon/BART Walnut Creek): 173
- Route 96X (BART Walnut Creek BART/Bishop Ranch): 570
- Route 97X (BART Dublin/Bishop Ranch): 112
- Route 98X (Martinez/BART Walnut Creek): 446

Ridership data for the Wheels routes was not available. In addition, a number of private employer shuttles operate in the area and serve BART stations, Bishop Ranch, and destinations outside of the corridor such as Silicon Valley and the Peninsula.

Commuters from this portion of Contra Costa County have been found to regularly park at three key BART stations. Specific details about who uses which station are not available but as a general guide, daily boardings and total number of parking spaces at these stations access are as follows:

- West Dublin – 3,700 daily boardings; 1,190 spaces
- Dublin/Pleasanton – 8,000 daily boardings; 4,213 spaces
- Walnut Creek – 6,800 daily boardings; 2,454 spaces
- Lafayette – 3,700 daily boardings; 1,907 spaces
- Pleasant Hill – 7,300 daily boardings; 2,835 spaces

It should be noted that spillover parking often occurs on adjacent streets and privately-owned parking areas. This indicates that these stations have parking shortages.

## Summary of Corridor Characteristics

Portions of the I-680 corridor between Walnut Creek and Dublin currently experience delays during peak commute hours due to congestion from high demand. As more people are expected to live and/or work in the area in the future, congestion will likely worsen and continue to be the number one cited problem for residents of the Bay Area. Based on an analysis of the travel patterns of the users of I-680, a list of key points regarding the needs of I-680 users has been developed. These key points are listed below:

- Current freeway congestion affects all corridor users. Portions of the corridor are heavily congested in both the A.M and P.M. peaks, in both the northbound and southbound directions. The segments with the highest delays in the northbound direction are around Sycamore Valley Road, Crow Canyon Road, between Diablo Road and El Cerro Boulevard; the segments with the highest delays in the southbound direction are around Bollinger Canyon Road, Sycamore Valley Road, and between El Pintado Road and Stone Valley Road. In addition, the peak is spreading, and now includes a four hour time frame in the mornings (6 A.M. to 10 A.M.)
- Freeway congestion affects most residents and workers. A large number of residents work outside of the Tri-Valley area. Of the study area residents, 52 percent work within the

corridor, 36 percent work toward the north and 16 percent work toward the south. These travel trends for workers and residents should not change substantially through the year 2040.

- Just under half of the I-680 freeway users are traveling non-stop through the study area. An origin/destination analysis on either end of the corridor suggests that about 37 percent of southbound trips and 40 percent of northbound trips are through trips in the A.M. peak hour.
- A notable number of residents use transit, with BART as the largest provider of transit trips. A connection to the regional transit system (BART) is available at either end of the corridor, although parking is severely restricted at both ends. For a suburban area, a high number of corridor residents use transit to commute to work (generally 6-8% with 14% in Walnut Creek), with nearly all of these trips occurring on BART (75-90% in Contra Costa County and 55-70% in Alameda County). This is likely attributable to the effectiveness of BART in serving the long commute of some local residents. In order to attract new riders to the transit system, there would need to be either an improvement in service (either rail or express bus), additional parking at BART stations, or fast shuttles to BART stations.
- With additional growth, congestion in the corridor will get worse. Although there are no major roadway expansions planned in the corridor, 2040 working population is forecasted to grow by 22 percent and employment by about 35 percent. This will cause traffic to be even worse than today resulting in slower speeds, longer queues, a spreading of the peak, and thus, more frustrated drivers. On the current 2+ HOV network, additional users will cause these lanes to approach capacity during both the A.M. and P.M. peak periods. For bus transit operators, congestion will impact both the efficiency and effectiveness of their operations as it will be difficult to enter, exit and use this portion of the I-680 corridor.

# 3 IDENTIFICATION AND SCREENING OF INITIAL INVESTMENT OPTIONS

## Initial Options

In the early stages of the study, the DKS Team and CCTA staff worked with the TAC and PAC to identify a broad range of potential investment options to be considered. Sixteen options were evaluated, covering multiple technologies and alignments focusing on the following five primary modal groupings:

- Bus Transit – Enhancing bus service by providing more service, better connections through park-and-ride lots, or installation of designated lanes along I-680.
- Ultra-Light Rail – Small or individual vehicle, low impact rail transit line to serve the I-680 corridor with technology similar to the Oakland Airport connector or the SFO AirTrain.
- Light Rail – Light rail transit line to serve the I-680 corridor powered by catenaries similar to Muni, or through hybrid inductive technology.
- Heavy Rail – Heavy rail transit line to serve the I-680 corridor using either traditional BART or Diesel Multiple Units similar to the eBART extension.
- Connected and Automated Vehicles – Adding infrastructure along I-680 to improve the functionality and efficiency of automated cars or the creation of a designated lane for automated cars.

## Screening Process

The initial investment options were screened to identify those that best fit within the objectives and constraints of this study. Each of the investment options was evaluated based on the screening criteria described below. The criteria were defined such that a high rating corresponds with a favorable outcome, while a low rating corresponds with less favorable impacts. The final two criteria do not follow the same rating system, but were deemed useful to the screening process. The screening criteria were:

- **Increase Person Throughput** – number of travelers that can be accommodated in the corridor. A greater number of travelers across all modes would receive a higher score.
- **Attractiveness to New Riders** – how attractive the strategy package is to new riders. An ability to attract a greater number of new riders, as opposed to easing the travel for existing riders, would receive a higher score.
- **Enhance Connectivity** – ability to integrate with existing systems, ease of transfer. Direct connections to existing, regional transit systems would receive a higher score.
- **Impact on Traffic Operations** – potential impact on freeway and surface street traffic operations, including delay, weaving, and level of service. An improvement in traffic operations would receive a higher score.
- **Minimize Right-of-Way Requirements** – amount of right of way required and potential availability of that right of way. No need for additional right of way would receive the highest score.

- **Community Acceptability** – public and political support for project. The greater anticipated support for the project would result in a higher score.
- **Policy Consistency** – consistency with current local and regional plans and policies. Strategy packages that are identified in existing plans would receive the highest score.
- **Minimize Construction Impacts** – potential impact that construction of the strategy package would have on the surrounding roadways and neighbors. Those strategies with the fewest direct impacts from construction would receive the highest score.
- **Minimize Environmental Impacts** – potential impact on natural and built environment, including visual and noise impacts. Those strategy packages with the least negative environmental impact would receive the highest score.
- **Cost** – General range of cost, including both capital and operating costs.
- **Markets Served** – lists the travel markets that the option would potentially serve, e.g., local vs. through trips; trips with an origin or destination in the corridor; peak vs. off-peak trips; commute vs. non-commute trips.

## Screening Results

For each of the sixteen initial investment options, a relative "score" was developed for each of the criteria and are presented in **Table 5**. For most of the criteria, circles are used to indicate positive to negative screening results. The more favorable an option is found to be, the more completely the circle is filled in. The less favorable, the less the circle is filled in. The scale used for each criterion is based on the range assessed for the options examined. Thus, the introduction of a completely new option could shift the relative scale. Because "markets served" is not inherently positive or negative, this information is provided as a purely qualitative listing.

No attempt was made to define an overall score by summing the individual ratings. This was because weighting between the criteria was not established (and is not part of the screening approach), and the relative scale between criteria varies. Further discussion for each Modal group is given below.

### Connected Vehicle/Automated Vehicle

Based on the scoring criteria, converting I-680 into a CV/AV facility has a better result under every criterion than the construction of a new exclusive median lane for connected vehicles. While a new lane would increase capacity in the short term, there are multiple safety issues with interaction between the CV/AV lane and the existing express and HOV lane. The cost and impacts from the construction of a new median lane would be much higher than the addition of CV/AV infrastructure improvements to the existing I-680 facility, and having a full CV/AV facility would have much higher potential for long-term improvements to efficiency, throughput, and safety.

### Bus Transit

Based on the scoring criteria, the addition of intelligent technology improvements and the expansion of bus service along the I-680 corridor has a better result than either of the I-680 busway options. Both of the busway options have a potential for higher cost and impacts, either from the construction of a new median lane, or from ramp treatments for the shoulder bus lane.

Improvements to the existing bus system will require minimal investment and it is consistent with existing policies and already planned and programmed transit improvements.

### Light Rail

Based on the scoring criteria, battery-powered Light Rail Transit had the best overall score among the options. Fewer traffic, environmental, and construction impacts are expected for a light rail alignment along the I-680 median than for installing rail through parallel arterials, which outweighs the added benefit of having an alignment closer to more destinations. The option of using technologically advanced battery-powered vehicles shows a potential improvement in cost and community acceptance.

### Ultra-Light Rail

Based on the scoring criteria, automated guideway transit along the I-80 right-of-way, similar to the Oakland Airport Connector, had a better score than the smaller vehicle Ultra Pod system installed along parallel arterials. While the Ultra Pod option had the potential for higher connectivity and a lower cost, the automated guideway transit would result in fewer environmental and construction impacts, and would require less right of way, which could result in a higher level of community acceptance.

### Heavy Rail

Based on the scoring criteria, an underground alignment of BART had a better score than either a parallel or I-680 median above-ground alignment option. Having an underground alignment could allow for in-line connections at Walnut Creek and West Dublin, which would require less transfers and construction at existing stations than the other alignments, that require stub connections. An underground alignment would also minimize right-of-way requirements along with environmental and construction impacts as compared to an above ground alignment. As a result, it would also have more community acceptance.

**Table 5: Scoring of Preliminary Options**

| Criteria | Connected Vehicle/ Autonomous | | Buses | | | Light Rail | | | | Ultra Light Rail | | Heavy Rail | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Expanded | I-680 Busway | | Catenary | | Battery Powered | | AGT | Ultra Pod | BART | | | DMU | |
| | I-680 Median | I-680 All-lanes | Various Routes | I-680 Median | I-680 Shoulder | Parallel Route | I-680 Median | Parallel Route | I-680 Median | I-680 Median | Parallel Route | Under-ground | Parallel Route | I-680 Median | Parallel Route | I-680 Median |
| Increase Person Throughput | ◑ | ◕ | ◑ | ◑ | ◑ | ◑ | ◑ | ◑ | ◑ | ◔ | ◔ | ◕ | ◕ | ◕ | ◕ | ◕ |
| Attractiveness to New Users | ◕ | ◕ | ◕ | ◑ | ◑ | ◕ | ◑ | ◕ | ◑ | ◑ | ◑ | ● | ◕ | ◕ | ◕ | ◕ |
| Enhance Connectivity | ● | ● | ◕ | ◑ | ◑ | ◑ | ◑ | ◑ | ◑ | ◑ | ◕ | ● | ◕ | ◕ | ◕ | ◕ |
| Minimize Impact on Traffic Operations | ◕ | ● | ● | ◕ | ◑ | ○ | ◕ | ○ | ◕ | ◕ | ◕ | ◑ | ◕ | ◕ | ◕ | ◕ |
| Minimize Right-of-Way Requirements | ◑ | ● | ● | ◑ | ◕ | ◕ | ◑ | ◕ | ◑ | ◑ | ◔ | ◑ | ○ | ◑ | ○ | ◑ |
| Community Acceptance | ◑ | ◕ | ◕ | ◕ | ◑ | ◔ | ◑ | ◑ | ◑ | ◑ | ◔ | ◕ | ◔ | ◑ | ◔ | ◑ |
| Policy Consistency | ◑ | ◑ | ● | ◕ | ◕ | ◔ | ◑ | ◔ | ◑ | ◔ | ◔ | ◔ | ◔ | ◔ | ◔ | ◔ |
| Minimize Construction Impacts | ◑ | ● | ● | ◑ | ◕ | ○ | ◔ | ○ | ◔ | ◔ | ○ | ◔ | ○ | ◔ | ○ | ◔ |
| Minimize Environmental Impacts | ◕ | ● | ● | ◕ | ◕ | ◔ | ◔ | ◔ | ◔ | ◔ | ◔ | ◔ | ○ | ◔ | ○ | ◔ |
| Capital and Operating Cost | $100 M to $500 M | <$100 M | <$100 M | $500 M to $3 B | <$100 M | $3 B to $6 B | $3 B to $6 B | $3 B to $6 B | $3 B to $6 B | $500 M to $3 B | $100 M to $500 M | $6 B to $12 B | $6 B to $12 B | $6 B to $12 B | $3 B to $6 B | $3 B to $6 B |
| Markets Served: Through Trips | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Markets Served: To/From Corridor Trips | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Markets Served: Peak Trips | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Markets Served: Off-Peak Trips | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Markets Served: Commute Trips | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Markets Served: Non-commute Trips | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Markets Served: Local Businesses and Shopping Trips | | | ✓ | | | ✓ | | ✓ | | | | | | | | |
| Markets Served: School Trips | | | ✓ | | | | | | | | | | | | | |

Legend:
○ Less positive
◔
◑
◕
● More positive
✓ Market served

# 4 OPTION PACKAGES DESIGNATED FOR FURTHER EVALUATION

Additional analysis was conducted for each of the four "top-priority" options to determine which might represent cost-effective investments for the corridor. This analysis began with a more detailed description of the investment option as summarized below.

## Top Priority Investment Options

**Enhanced Bus Service -** This option would provide transit service beyond the existing services and the planned expenditures and transit improvements programmed under Measure J. It would provide new park-and-ride facilities in the I-680 corridor between Walnut Creek and Dublin as well as frequent shuttle service to and from existing BART stations. The new transit service would operate during the peak and off-peak time periods. Existing express transit service (funded through Measure J) would be expanded to operate during the off-peak time period and, in some cases, more frequently during peak periods. Express bus and shuttle services using I-680 would be allowed to use existing and new auxiliary lanes and shoulder lanes hardened for bus operation if existing California Vehicle Code and Caltrans policy can be changed to allow bus use of shoulders. Local bus service would also be increased. Where appropriate and feasible, this option could include enhanced school bus service in the corridor to expand the number of schools served, potentially add routes and buses, and extend the time horizon of the TRAFFIX program to reduce local-street and corridor-wide congestion during school start and end times. This option would also explore and build upon new opportunities introduced by employer-based transit service provided by Sunset Development in Bishop Ranch, Google, Yahoo, Genentech, and others, by incorporating technology advances that improve operational efficiency.

**Elevated Tram** - This option would provide an above-ground guideway transit service with automated vehicles similar to transportation used at the San Francisco International Airport and the BART to Oakland International Airport connector. The elevated guideway would run in the I-680 median with stations spaced approximately every two miles and located adjacent to the freeway. This option would have connections to the Walnut Creek and West Dublin BART stations.

**BART** - This option would provide an underground tunnel for BART trains between the Walnut Creek and the Dublin/Pleasanton BART station with intermediate stations located at major activity centers in the corridor. This option would also connect directly into the Pittsburg/ Bay Point line at the Pleasant Hill Station and would have the potential to connect directly into the extension of the Dublin/Pleasanton line if it is extended to Livermore.

**Connected and Automated Vehicle (CV/AV) Support** - This option would support an emerging area of transportation technology that will enable automobiles and other on-road vehicles to get maximum benefit from vehicle automation and self-driving functions being incorporated into new car, truck and bus models. The success of this option will depend on a high level of adoption of automation functions and vehicle communication functions by

vehicle manufacturers and owners as well as integration of roadside communication technology with CV/AV-equipped vehicles.

## Evaluation of Top Priority Options

The following criteria were used in the evaluation of the top priority investment options.

- Capital and Operating Costs
  - Estimation of the initial capital and construction costs and ongoing operation and maintenance costs for each option
  - Feasibility of funding the project based upon existing and forecast revenues
  - Feasibility of operating and maintaining each option
- Travel Time Impacts
  - Comparison of the expected changes in travel times due to new transportation options, assuming implementation today
  - Note: Travel time estimates depend on the assumed level of service and connections with other transportation modes
- Potential Mode Shift
  - Evaluation of the impact of the new transportation options on changing travel behavior, including transit ridership and mode shift
- Markets Served
  - Analysis of the types of trips that each option would be able to serve within the corridor
- Connectivity
  - Evaluation of the ability to access the new transportation options with existing modes of transportation
- Construction Impacts
  - Evaluation of the temporary impact of the options during the construction phase
- Potential Environmental Impacts
  - Review of the potential impacts to the existing land use, circulation, noise, biological, and other resources
- Conflicts with Other Traffic
  - Evaluation of the impact of the new transportation options on circulation of existing modes of transportation
- Constructability Issues
  - Special considerations of the construction, design and feasibility of each option, including consideration of time frame for likely implementation, potential for phased implementation and timing for usable segments

## Capital and Operating Costs

The estimated initial capital and construction costs and ongoing operation and maintenance costs for each option are shown in **Table 6**. The cost of the Elevated Tram and BART options had substantially higher capital costs than the Enhanced Bus and CV/AV options. The ongoing costs for the Enhanced Bus option were similar to the Elevated Tram and about 22% of the BART option. The CV/AV option had the lowest capital and operating costs of all the options.

**Table 6: Comparison of Capital and Operating Costs**

| | Enhanced Bus Service | Elevated Tram | BART | Connected and Automated Vehicles |
|---|---|---|---|---|
| Capital Construction and Vehicle Costs | $51 - $54 M | $2 - $3.4 B | $6.6 - $8.6 B | $29 M |
| Annual Operations and Maintenance | $18.1 M | $27 M | $82 M | $600,000 |
| Key Elements | 4 new park-and-ride facilities:<br>• 1143 spaces<br>• Passenger amenities<br>42 standard buses<br>6 park-and-ride shuttle routes<br>Increased off-peak express and local bus service<br>Increased school bus service | 17 miles<br>4 intermediate stations, with parking<br>2 end stations<br>Rolling stock<br>10-minute peak service | 19 miles<br>3 intermediate stations, with parking<br>2 end stations<br>Rolling stock<br>10-minute peak service | 35 miles<br>Vehicle-to-Infrastructure communication<br>Vehicle detection and surveillance<br>Central management system<br>High-visibility pavement markings<br>Increased roadway maintenance |
| Funding Feasibility | Feasible | Somewhat Feasible | Low Feasibility | Feasible |
| Phasing Ability | Yes | No | No | Yes |

Additional analysis was performed to reduce the cost for the rail options and examine alternate alignments. As shown in the Appendix, the alternate alignments included options for the Elevated Tram and BART going only as far as San Ramon and an alignment with BART being connected to the Lafayette Station rather than the Walnut Creek station. If terminated in San Ramon, the length of the Elevated Tram option would be about 75 percent of the original length and the costs would be reduced proportionally: approximately 75 percent of the original costs. An Elevated Tram option was also investigated that connected the Lafayette Station directly to a San Ramon Station going over the hills rather than along I-680, but the grades through the hills would be prohibitive and there would be a much higher environmental impact than the freeway median alignment. For these reasons, cost estimates were not prepared for this option.

Similarly, terminating the BART line at San Ramon would result in a line about 71 percent of the length of the original option and overall costs would be reduced by approximately the same percentage. There were similar results for the option of a BART line between the Lafayette station and San Ramon. The length of the option would be about 83 percent of the original option connecting Walnut Creek and Dublin; overall costs would be reduced by approximately the same percentage.

Based on the additional analysis of the rail options, it appears that even the shorter options that only go as far as San Ramon would still be beyond the feasible range of costs. An Elevated Tram would cost at least $1.5 billion in capital cost and BART at least $4.9 billion.

## Travel Time

Travel times were estimated for the following origin and destinations:

- Danville to San Francisco
- Bay Point to San Ramon
- Walnut Creek to Dublin

The travel modes included single-occupant vehicle (SOV), high-occupancy vehicle (HOV) and transit. Existing travel by SOV was assumed to only use local streets and general purpose freeway lanes. In the future, SOVs will have the option of using the HOV lane for a fee once the current implementation of the express lane is completed. The HOV trips were assumed to use designated HOV lanes where available. Travel times for transit trips included the access time for the service, expected wait times at transfer points, the in-vehicle time and egress.

**Table 7** illustrates the expected impact of each of the options by travel mode, as compared to existing travel times for the origin and destination pairs.

**Table 7: Estimated Travel Time Impacts Compared with Existing**

| | | Estimated Change in Travel Time | | | |
|---|---|---|---|---|---|
| | **Existing Travel Time** | **Enhanced Bus Service** | **Elevated Tram** | **BART** | **Connected and Automated Vehicles** |
| Danville to San Francisco | | | | | |
| SOV | 66 minutes | Potential Reduction | Potential Reduction | Potential Reduction | -5 minutes |
| HOV | 56 minutes | | | | -3 minutes |
| Transit | 81 minutes | -15 minutes | -24 minutes | -21 minutes | -3 minutes |
| Bay Point to San Ramon | | | | | |
| SOV | 75 minutes | Potential Reduction | Potential Reduction | Potential Reduction | -6 minutes |
| HOV | 57 minutes | | | | -4 minutes |
| Transit | 65 minutes | -8 minutes | -21 minutes | -18 minutes | -4 minutes |
| Walnut Creek to Dublin (West) | | | | | |
| SOV | 35 minutes | Potential Reduction | Potential Reduction | Potential Reduction | -7 minutes |
| HOV | 25 minutes | | | | -5 minutes |
| Transit | 47 minutes | -10 minutes | -7 minutes | -9 minutes | -5 minutes |

Note: SOV and HOV travel times may also be influenced by reduced traffic as a result of a mode shift to transit. This effect will be estimated upon completion of modeling analysis of each transit option.

For comparison purposes, SOV travel times were estimated using Google Maps for a Wednesday at 8:00 am arrival at the destination. HOV travel times were based on an assumption of continuous free-flow (60 mph) in the HOV lanes. Transit travel times were based on existing services and schedules with arrival time at the destination between 8:00 am and 9:00 am. If multiple options existed, the fastest option was assumed.

Trips were assumed to originate from a transit center, BART station or park-and-ride lot, and were not representative of door-to-door travel times. Station access time was estimated as one half of the current scheduled headway. For example, a trip that begins with a BART trip with trains arriving every 10 minutes would have station access time of 5 minutes. Similarly, the assumed times for transfers were based on service frequency. The transfer time was assumed to be the typical headway of the connecting service. For example, a trip that begins as BART trip with a transfer to a bus arriving every 10 minutes would have a transfer time of 10 minutes.

By transit, it currently takes 81 minutes to travel from Danville to San Francisco, 65 minutes to travel from Bay Point to San Ramon, and 47 minutes to travel from Walnut Creek BART to the Dublin/Pleasanton BART. The analysis assumed that the future travel times would be consistent with the existing service.

The existing SOV travel times, based on congested travel in Google maps, and assuming an 8:00 am arrival on a Wednesday, are 66 minutes to travel from Danville to San Francisco, 75 minutes from Bay Point to San Ramon, and 35 minutes to travel from Walnut Creek BART to West Dublin/Pleasanton BART.

The existing HOV travel times, based on the SOV travel times and time savings from uncongested travel in the HOV lanes, are 56 minutes to travel from Danville to San Francisco, 57 minutes from Bay Point to San Ramon, and 25 minutes to travel from Walnut Creek BART to West Dublin/Pleasanton BART.

The travel time assumptions and results for each option are summarized below.

### Enhanced Bus Service

Travel times for expanded bus service was based on the assumption of direct service between park-and-ride lots/transit centers and BART stations, similar to the existing service. The analysis assumed more frequent service, typically 10-minute headways, with less wait time for station access and transfers. **Table 8** compares the existing transit service with the service assumed for this option.

**Table 8: Comparison of Existing and Enhanced Bus Service**

| Travel Segment | Type of Operation | Existing Service | Enhanced Service |
|---|---|---|---|
| Danville to Walnut Creek | Peak Period Express | 1-2 buses per hour from Sycamore Park and Ride | Up to 6 buses per hour |
| | Off-peak Express | No service | Midday and weekend service |
| | Local | All-day service | Increased off-peak weekday service |
| Walnut Creek to San Ramon | Peak Period Express | 6-7 buses per hour to San Ramon Transit Center | 6-7 buses per hour with potential reduced stops |
| | Off-peak Express | Peak-direction after AM peak | Bi-directional midday and weekend service |
| | Local | All-day service | Increased off-peak weekday service |
| Walnut Creek to Dublin | Peak Period Express | 2 buses per hour | Up to 6 buses per hour |
| | Off-peak Express | No service | Midday and weekend service |
| | Local | All-day connecting service | Increased off-peak weekday service |
| Four new park-and-ride locations | Peak Period Express | N/A | New shuttle service to BART |
| School Service | School pickup and drop-off and start and end times | 11 schools | Additional schools served |

For the Danville to San Francisco trip, an existing express bus service operates between the Sycamore Valley Road Park park-and-ride lot in Danville and the Walnut Creek BART station. For the Walnut Creek to Dublin trip, an existing express bus service operates between the Walnut Creek and the Dublin/Pleasanton BART station. The analysis assumed that the service would operate to the West Dublin/Pleasanton BART station with travel times consistent with existing express service. For the Bay Point to San Ramon trip, the analysis assumed a more direct trip than the existing service, which makes four stops between the I-680 corridor and the San Ramon transit

center. Some of the existing bus service is 100% subsidized through transportation demand management programs. Similar to the existing transit options, some transit trips would include a portion of the trip on BART, and assumed to be the existing travel times.

The estimated travel times were 66 minutes to travel from Danville to San Francisco, 57 minutes from Bay Point to San Ramon, and 37 minutes to travel from Walnut Creek BART to West Dublin/Pleasanton BART.

### Elevated Tram

The Elevated Tram option assumed an average operating speed of 42 miles per hour, based on the capabilities of the technology, and 20 seconds per stop at intermediate stations. The service was assumed to operate every 10 minutes during the peak period. A transfer time of 5 minutes was assumed at BART stations. The service was assumed to end at the West Dublin BART station, due to the track geometry requirements. For passengers connecting to the Dublin/Pleasanton station, additional time was added to the trip for the transfer and travel time between stations.

The estimated travel times were 57 minutes from Danville to San Francisco, 44 minutes from Bay Point to San Ramon, and 32 minutes from Walnut Creek BART to the West Dublin/Pleasanton BART Station. For a final destination of the Dublin/Pleasanton BART station, the travel time was estimated to be 40 minutes.

### BART

The BART option assumed an average speed of 42 miles per hour, based on the current scheduled service on the Pittsburg/Bay Point Line, and 20 seconds per stop at intermediate stations. The service was assumed to operate every 10 minutes in the peak period. The service was assumed to end at the Dublin/Pleasanton BART station, due to the track geometry requirements. For passengers connecting to the West Dublin/Pleasanton station, additional time was added to the trip for the transfer and travel time between stations. The Danville to Walnut Creek trip included walking transfer time at Walnut Creek due to the distance between the stations.

The estimated travel times were 60 minutes from Danville to San Francisco, 47 minutes to travel from Bay Point to San Ramon, and 30 minutes from Walnut Creek BART to Dublin/Pleasanton BART. For a final destination of the West Dublin/Pleasanton BART station, the travel time was estimated to be 38 minutes.

### Connected and Automated Vehicles

There are two components of travel time affected by the Connected and Automated Vehicle option: reduced recurring congestion caused by increased capacity due to more efficient usage of existing lanes and ramp meters, and reduced non-recurring incident based delay due to fewer primary and secondary incidents. Both of these components are sensitive to market penetrations and the capabilities of vehicles, both of which will continue to increase over time. This analysis assumes that there is almost complete market penetration with 95% of vehicles traveling along the corridor possessing automation, and that the technology has advanced to Limited Self-Driving Automation (Level 3) where the driver cedes full control of all safety-critical functions to the vehicle in almost all circumstances while on the freeway. In addition to direct reduction of

travel time, connected and automated vehicles provide a trip with more productive time and reduced stress. This option does not preclude carpooling or ridesharing arrangements.

### *Recurring Congestion Delay*

Recurring congestion occurs at locations along the corridor where demand is larger than the capacity of the roadway. While the study corridor provides multiple lanes of capacity throughout the corridor, congestion typically occurs where on-ramps introduce additional demand or where one of the lanes transitions to an express/HOV lane and the number of general traffic is reduced. Whenever the demand at these locations is more than the capacity, a bottleneck is created, and congestion builds up until the demand drops below the capacity, usually at the end of the peak period.

Existing traffic meters at freeway on-ramps are designed to reduce bottlenecks by controlling the rate at which traffic enters the freeway. The traffic metering rates at freeway on-ramps are based on historical volume data. As a result, there is no direct connection between current traffic conditions and the metering rate. Connected infrastructure would have the ability to determine the current volume of traffic at each ramp and provide a dynamic, adaptive metering rate that would reduce bottlenecks on the freeway, while preventing spill-over into adjacent local roads.

Connected infrastructure would also use roadway vehicle detection data to identify the location of congestion and communicating the measured speed and density of traffic, allowing a connected car to respond much sooner to an upcoming slowdown or stop by reducing speed in advance of the vehicle ahead. This will have the result of reducing the number of incidents and secondary incidents. In combination with a high market share of automated vehicles allowing for platooning with shortened vehicle headways, higher flow coupled with improved speed harmonization would be possible, essentially increasing the capacity of the existing lanes. Current research shows capacity begins to increase with 40% market penetration and that as market penetration approaches 100%, capacity of freeway lanes can increase from 2000 vehicles per hour per lane (vphpl) currently up to 4000 vphpl[2]. However, studies show that increasing capacity of the corridor would not necessarily increase vehicle speed, especially under free-flow conditions or away from bottlenecks[3]. Assuming current demand, the increased capacity will have the effect of reducing the number of active bottlenecks which result in congestion along the corridor. The effect on travel time will be dependent on how demand increases over time as compared with the increasing market share of connected vehicles and resulting capacity of the roadway. It is estimated that the travel time effect would be a reduction of approximately one to three minutes depending on the length of the travel segments.

[2] Steven E. Shladover. "Highway Capacity Increases from Automated Driving." California PATH Program, July 2012

[3] Jane Bierstedt et Al., "Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity", January 2014

### *Non-recurring Incident Based Delay*

Based on historic crash data, I-680 in the study corridor experiences an average of 50 crashes a year during the AM weekday commuter peak (6:00 am to 9:00 am). This represents one crash a week for each commuter period. If the average crash conservatively adds 60 minutes of delay to each commuter, and it takes an hour for the resulting queue to dissipate, then assuming a three-hour commute period, the average driver experiences an extra 4 minutes of delay per day.

By using vehicle detection technology identify the location of congestion and communicating the measured speed and density of traffic ahead of the vehicle, a connected car can respond much sooner to an upcoming slowdown or stop by reducing speed in advance of the vehicle ahead. This will have the result of reducing the number of incidents and secondary incidents. One study shows an expected reduction of 80% on incidents with full market penetration of automated vehicles[4]. Providing on-board displays of Integrated Corridor Management information (without the use of overhead gantries) would also allow drivers to modify their route to avoid congestion. As a result, on average, a reduction of four minutes of non-recurring incident based delay per day is expected for the general purpose lanes, with a smaller impact on HOV and transit users.

## Potential Mode Shift, Transit Ridership and Cost Effectiveness

The estimated mode shift will depend on the potential reduction of travel time and the level of service offered. The level of service also influences the travel time, as more frequent service was assumed to result in less wait time and transfer time.

Transit ridership was estimated using a special corridor transit ridership model that is sensitive to park-and-ride availability for transit. For the Enhanced Bus option, the total boardings, including the a.m. and p.m. peak period was estimated to be about 2,300 to 2,800. Approximately 75% of the ridership was generated by traditional commuters accessing the shuttles by car via park-and-ride. The remaining 25% of the ridership is a mix of the reverse commute and access by other modes - the largest number made up of drop-off.

The ridership for the rail options was estimated using the shuttle access proportions as a guide. Because the travel times are similar, the ridership was assumed to be roughly equivalent between the Elevated Tram and BART options. The corridor model used in the study estimated about 2.3 daily transit trips are generated per parking space from the corridor. If 3,000 parking spaces would be provided would be provided for each of the rail options, they would produce an estimated 6,200 to 7,600 trips from the new rail stations in the corridor. Assuming that the additional trips from the reverse commute and other access modes is similar to the enhanced bus, the total ridership from the rail lines would be approximately 8,200 to 10,000, or about 3.5 times the Enhanced Bus option. Considering the large cost associated with the rail options, the Enhanced Bus is much more cost effective on a cost-per-rider basis.

[4] US Department of Transportation Intelligent Transportation Systems Joint Program Office, http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm

The Connected and Automated Vehicle option was not expected to contribute to a shift to or from the transit mode because it would mainly reduce the travel times for the SOV. Currently the majority of transit trips within the study corridor are local trips or trips to and from BART. As the transit travel time to BART using bus service is currently slower than travel time by car, transit users were assumed to not have access to a car, unable to find sufficient parking at BART, or choose to use transit for other reasons. As the Connected and Automated Vehicle option would not address any of these reasons and would decrease the travel time for cars, there was not expected to be a significant shift to or from the transit mode. However, this option may facilitate ride-sharing and promote increased vehicle occupancy.

## Markets Served

The various investment options have the potential to serve a range of travel markets. This evaluation considers factors such as connectivity to other systems, frequency of stops or access points within the study area, and time of operation. The following markets were identified to compare the options:

- Local Trips
- Through Trips
- To-From Corridor
- Peak Period
- Off-Peak Period
- Commute Trips
- Non-commute Trips

All of the options identified would serve each of the markets, with the exception of BART, which would not serve local trips.

## Connectivity with the Existing System

The various options provide different connections to the communities they serve. Some options would operate in a manner that requires additional connections such as park-and-ride lots or local transit services in order to connect riders with the service. Other options would additionally offer walking and biking connections. All of the transit options would require a transfer at a BART station to access areas outside the study area.

For the transit options, the potential locations of park-and-ride lots and rail stations were identified. Access to the park-and-ride lots and rail stations was evaluated relative to local bus service, pedestrians, bicycle, and automobiles. For the Elevated Tram and BART options, the ability to transfer between service in the I-680 corridor and the existing BART stations was also evaluated. For the Connected and Automated Vehicles option, no new connections, such as access ramps or dedicated lanes, were assumed.

### Enhanced Bus Service

The Enhanced Bus Service option would expand park-and-ride options for commuters able to drive to park-and-ride locations near the freeway. It would help to reduce peak-hour congestion on the freeway. However, this option is likely to provide more connection opportunities during commute hours than during off peak hours. This alternative is most attractive to commuters that have auto access. Coordination with and accommodations for private employer shuttles, demand-responsive transportation services, and pick-up and drop-off activity, and pedestrian and bicycle access would increase the number of potential connections. Because the shuttle service would directly link the park-and-ride lots to BART without intermediate stops, the option would serve those with origins and destinations outside the study area.

The additional school service in this option would also expand travel options and offer new connections to students and their schools via transit.

### Elevated Tram

The alignment for this option is along the freeway. This option, like the Enhanced Bus option, will serve as a park-and-ride. Users would also have the option to drive (or be picked up/dropped off), walk, bike or use local transit to access the stations and reach local destinations. This option would connect with many locations within the study area and would benefit from additional connections for those traveling within and outside of the study area.

### BART

The stations in this option would be in areas of commercial development. This would provide connection to those employed in the commercial areas within Danville and San Ramon as well as local residents employed near other parts of the BART system. The station locations would also provide walk and bike connections. Given a comprehensive safe routes to transit project this option has potential to provide the most active transportation connections as well as providing auto access. The BART option would also interline with existing service at Pleasant Hill station and serve areas to the east. This option could also be connected with the potential extension to Livermore.

### Connected and Automated Vehicles

This option is not expected to have a direct effect on connectivity; however more efficient operation of the roadway and a reduction in incidents would potentially have the effect of reducing travel time for express buses using the freeway, and therefore improve connectivity for transit users. Fully automated vehicles may have the ability to provide last-mile connections for transit users, for example by using self-parking capabilities to pick up and drop off at transit connections, but the technology is not dependent on the infrastructure investments considered for the I-680 corridor.

## Construction Impacts

The footprint for each option was laid out in Google Earth .KML format to identify the potential construction impacts adjacent to the proposed right-of-way, based on existing land use. Construction for the park-and-ride lots for the Enhanced Bus Service option was assumed to be at-grade. The majority of construction for the Elevated Tram option was assumed to be above

grade, with at-grade construction at the station areas and the support structures. The BART option was assumed to be constructed mostly underground by tunneling, with cut-and-cover construction at the station areas. In addition, the connections at the existing Walnut Creek and Dublin/Pleasanton stations would require substantial construction. For the Connected and Automated Vehicles option, it was assumed that the vast majority of construction would take place within the I-680 right-of-way. For all options, the surrounding communities would be exposed to dust, noise, construction traffic and movement of construction equipment, particularly during construction of station areas. The evaluation of other construction impacts is summarized below.

- Enhanced Bus Service: Construction for new park-and-ride locations would temporarily reduce street and freeway capacity and impact traffic, transit, pedestrian, and bicycle circulation.
- Elevated Tram
    - Construction would temporarily reduce street and freeway capacity and impact traffic, transit, pedestrian, and bicycle circulation.
    - Surrounding communities would be exposed to dust, noise, construction traffic and movement of construction equipment, particularly during construction of station areas
    - Significant visual impacts will be present along the freeway.
    - Construction activity would disrupt normal vehicular access on roadways crossing under or over the freeway.
- BART
    - The majority of construction would be performed underground. Cut and cover construction, expected only to be used near station areas, would reduce street capacity and impact traffic, transit, pedestrian, and bicycle circulation.
    - Access to portions of the Iron Horse Trail would be temporarily disrupted.
    - Normal vehicular access would be disrupted at crossings.
    - Construction would cause visual obstructions on the Iron Horse Trail.
    - Construction activities would be close to homes along the Iron Horse Trail
    - BART service may be temporarily disrupted in making the track connections with existing infrastructure.
    - The I-580 and Hacienda Drive interchange would be impacted to accommodate construction of additional rail car storage tracks.
- Connected and Automated Vehicles
    - Construction would temporarily reduce freeway capacity and impact traffic circulation, particularly during lane striping and installation of in-potential pavement sensors.

- Locations with a lack of median width would require median lane closures to install interconnect and monitoring components.

## Potential Environmental Impacts

Similar to the Construction Impacts, the proposed right-of-way for each improvement options was compared with the existing land use and biological resources. The assessment of potential impacts was based on comparison of the project areas with information obtained from the most recent Contra Costa County General Plan. Field investigations were not conducted. It is expected that any option that moves forward will be the subject of further study, during which field observations for resources present along each route will be observed in the field. The potential environmental impacts for each investment option were based on information obtained from the most recent Contra Costa County General Plan.

The following environmental resource factors California Environmental Quality Act were reviewed:

- Aesthetics
- Agricultural resources
- Air Quality
- Biological Resources
- Cultural Resources
- Geology and Soils
- Greenhouse Gases
- Hazards and Hazardous Materials
- Hydrology and Water Quality
- Mineral Resources
- Noise
- Traffic Impact
- Population and Housing

Based on this analysis, none of the options were expected to have significant negative effects on the environment outside of the temporary construction impacts. The underground tunnel for the BART option would potentially have an impact on geology and soils and the Elevated Tram option would potentially impact the aesthetics in the corridor. Finally, the park-and-ride lots and station areas may have noise and traffic impacts and affect population and housing, depending on their location and amount of private property required (assumed to be minimal). All of the options have the potential for a positive impact to air quality and greenhouse gas emissions.

## Conflicts with Other Traffic

This section examines whether an investment option would increase or reduce potential conflicts with vehicles as well as pedestrian and bicycles on the roadway network. However, this is limited to potential conflicts and does not take into consideration potential changes in traffic due to mode shifts or patterns. Furthermore, this does not include impacts during construction. Listed below is a summary of traffic conflict evaluation.

- Enhanced Bus Service: Increased activity around park-and-ride locations may lead to local traffic conflicts; additional transit service on I-680 may increase traffic conflicts at the freeway access points; schools with new bus service may need to make accommodations for buses to coexist with pickup and drop off by private vehicle.
- Elevated Tram: Increased activity around station locations may lead to local traffic conflicts; no impact to freeway due to fully grade-separated alignment.
- BART: Increased activity around station locations may lead to local traffic conflicts; no impact to freeway due to fully grade-separated alignment.
- Connected and Automated Vehicles: potential interaction with traffic at freeway ramps. Occupancy detectors would prevent any spillover from slower metering rates caused by adaptive ramp meters. As a result, no conflict is expected with other traffic.

## Constructability Issues

This section is intended to highlight issues related to the constructability, design, of feasibility of each option. Special challenges with construction techniques, staging and site access, and integrating the proposed options with the existing built environment were identified. Due to constraints of this study, these issues could not be fully addressed and would need to be examined as part of subsequent studies prior to implementation. The constructability issues for each option are summarized below.

- Enhanced Bus Service
    - Land acquisition for park-and-ride lots is a potential issue
    - Operating capacity and service coordination of local transit agencies and potentially with private operators
    - Operation of buses on the shoulders of I-680 would require a change in Caltrans policy and the California Vehicle Code that prohibit use of the shoulders by buses, but Caltrans is in the process of developing guidelines for a pilot program to test bus use of shoulders. Bus-on-shoulder operations have been successfully implemented in Minnesota, Illinois and North Carolina with little impact on safety.

- Elevated Tram
  - No conflicts with freeway due to fully grade-separated alignment
  - Construction could be phased to correspond to funding availability, but overall cost are likely to exceed the potential funds available
- BART
  - Integration with existing infrastructure is a potential issue
  - Subsurface conditions are not fully known. New test borings would have to be obtained since the existing log of test borings are outdated and does not contain sufficient information.
  - The San Ramon Creek and South San Ramon Creek run parallel to the Iron Horse Trail and cross the right of way south of Greenbrook Dr. and south of Alcosta Blvd, respectively.
  - The location of the dumping area would need to be relatively close to the construction area and easily accessible by dumping trucks since the majority of their time will be spent driving from the dumping area to the site and back to the dumping area.
  - Construction could be phased to correspond to funding availability, but overall cost are likely to exceed the potential funds available
- Connected and Automated Vehicles
  - Rapidly-developing technology may require continual upgrades and frequent maintenance. Preferably, the capabilities of the system should be able to be upgraded purely through software upgrades.
  - The full potential of this alternative will also depend on the continuing evolution of legislation regarding the legality and safe operation of automated vehicles on public roadways. Legislation allowing increased speed limits for all vehicles on highways could also increase the efficiency of the corridor.

## Evaluation Summary

The analysis of the top priority options showed that investments in transit and technology would yield significant transportation benefits in the corridor. Differences in overall cost and cost-effectiveness led to a recommended investment package as described below.

### Elevated Tram and BART Underground

The Elevated Tram and BART underground would require the largest capital investment and significant operating funds. Potential travel time savings and ridership were greater than the Enhanced Bus Option; however they were not proportional to their higher costs. The other evaluation criteria yielded similar results between the transit options, although the construction of the rail options, and BART in particular, would carry large risks.

Based on additional analysis of the rail options, it appears that even the shorter options that only go as far as San Ramon would still be beyond the feasible range of costs. An Elevated Tram would cost at least $1.5 Billion in capital cost and BART at least $4.9 Billion. Ultimately, the rail options were not recommended because of the high costs relative to potential benefits.

### Enhanced Bus and CV/AV

Features of the Enhanced Bus and CV/AV options were combined to form the recommended option. Because of the complementary features of the advanced technologies and transit, and the potential benefits to other traffic on the I-680 corridor, the recommendation includes bus-on-shoulder operations for buses, active traffic management technology on I-680 and the use of demand-responsive transit using Connected Shared Automated Vehicles to serve the park-and-ride lots. The details of the recommended option are discussed in the following section.

# 5 RECOMMENDATION FOR PREFERRED INVESTMENT OPTION

The recommended strategy for the I-680 corridor would improve transit service and capacity by providing additional local and express bus service, new park-and-ride facilities with shuttle service to BART, and provide operational benefits for buses by reconstructing segments of the I-680 shoulder and extending auxiliary lanes between ramps to allow buses to use these lanes to bypass traffic congestion in the general purpose lanes. Shared-use mobility elements would be incorporated into the transit-enhancement elements of the strategy. Existing and proposed park-and-ride facilities would serve as Smart Mobility Hubs with passenger information and amenities, secure bike parking, and access to bike sharing, car sharing, dynamic ridesharing, and demand-responsive transit services.

The recommended investment strategy would also implement a suite of advanced technologies and techniques known as Innovative Transportation Systems Management. This package includes support for connected and automated vehicles on I-680 using new communication technologies and high-visibility pavement markings. Active Traffic Management would be used to monitor traffic conditions, provide information to drivers and to connected vehicles, and improve efficiency through techniques such as adaptive ramp metering and dynamic lane use. Connected Shared Autonomous Vehicles would provide demand-responsive transportation between transit hubs, residences, and businesses using driverless electric vehicles operating on local streets.

The following sections sheets summarize the key features of the recommended strategy, which are grouped into four categories:

1. Enhanced Bus Service
2. Connected and Automated Vehicle Support on I-680
3. Active Traffic Management
4. Demand-Responsive Transit Service (using Connected Shared Autonomous Vehicles on local streets)

Implementation of the strategy would allow integration of transportation infrastructure, management, technologies, policies and operational efficiency and foster collaboration among agencies and across jurisdictions in the I-680 corridor.

## Enhanced Bus Service

This package of improvements would provide additional transit service in the corridor. This would include construction of new park-and-ride facilities with shuttle service to BART; addition of express, local and school buses services; and addition of auxiliary lanes and reconstruction of shoulder lanes on I-680 (as needed) to allow buses to operate in the auxiliary lanes and shoulders to bypass congestion in the general purpose lanes.

- Additional Park-and-Ride Lots with Smart Mobility Hubs – Four new park-and-ride facilities would be constructed near I-680 between Walnut Creek and San Ramon. The

facilities would accommodate a total of 1,100+ surface parking spaces, provide passenger amenities, and potentially incorporate car sharing, bike sharing, demand-responsive services and employer-based transportation.
    - 1143 new Parking Spaces
    - Smart Mobility Hubs with Passenger Amenities at Each Park-and-ride Facility

- New Shuttle Service and Enhanced Local and Express Bus Service – Six shuttle routes would provide direct service between park-and-ride lots and BART stations (2 from existing and 4 from new facilities). Current express and local service would be increased during the off-peak periods to serve employment centers and destinations throughout the corridor.

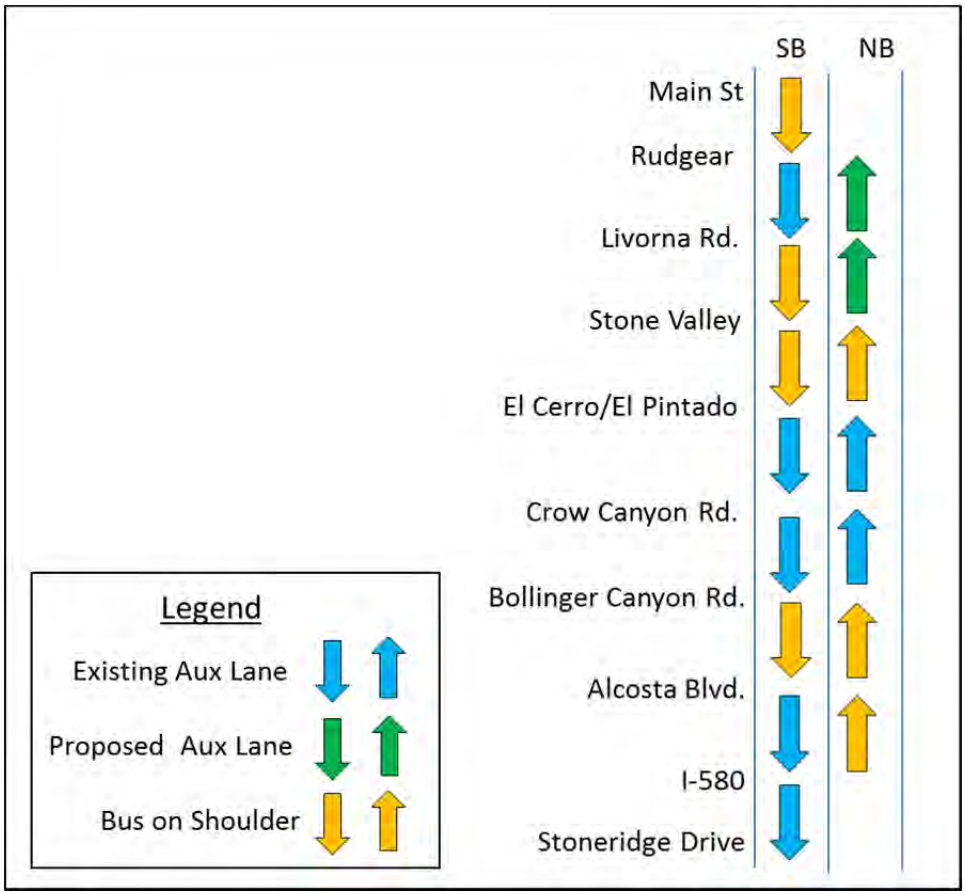
- Bus on Shoulder Operation (I-580 to SR-24) – Shuttle and express buses could operate on I-680 in the express lanes or in existing or expanded auxiliary lanes and in shoulder lanes to avoid traffic congestion in the general purpose lanes which would have to be traversed to get to the express lanes. **Figure 4** illustrates where buses would be able to operate in existing auxiliary lanes, in new auxiliary lanes added as part of the investment package and consistent with the recommendations of the CSMP, and in shoulders hardened for use by transit vehicles as part of the investment package. Implementation of the Bus-on-Shoulder operation would require a change in California Vehicle Code and a change in Caltrans policy.

- Increased School Bus Service – The existing TRAFFIX Program supported by Measure J would be expanded and/or supplemented.

- Additional Transit Vehicles – New vehicles would include buses needed for shuttle service, buses for expanded local and express service and school buses.
    - 32 New Transit Vehicles for Shuttle Service (Standard, Vehicle Assist or Autonomous)
    - 10 New Standard Buses for Expanded Express and Local Service
    - 20 New Buses for School Bus Service

The Enhanced Bus package would be a flexible approach, and the specific locations of the park-and-ride lots and transit service patterns would need to be further defined during the design and implementation phase. The number of additional transit vehicles was determined by an assumed frequency and estimated travel times for the service between the park-and-ride lots and the BART stations. The service levels would be adjusted during implementation to balance capacity and ridership, and the fleet size could be scaled up over time.

**Figure 4: Potential Bus on Shoulder and Auxiliary Lanes on I-680**




## Connected Vehicle and Automated Vehicle Support

This package of improvements would facilitate Limited Self-Driving Automation (Level 3), where the driver cedes full control of all safety-critical functions to the vehicle in almost all circumstances while on the freeway. Enhanced pavement markings and maintenance would provide improved visual guidance and reduced interference for automated driving functions. Transit vehicles, automobiles and their drivers would receive information about upcoming road and traffic conditions, via two-way vehicle-to-infrastructure communications along the corridor, with the goal of preventing incidents. The roadside equipment and connected vehicles would also provide information for managing the freeway. These improvements were assumed to be implemented between the Benicia Bridge and SR-84.

- Vehicle-to-Infrastructure Communication – Advanced radios and processors along the roadway would have capabilities to send and receive data to and from vehicles. This could include information on upcoming traffic conditions and lane closures.
    - Vehicle Location, Speed and Density Feeds to Management Center
    - Road Condition and Weather Conditions Feeds to Management Center

  - Vehicle Information Feed from Incidents to and from Management Center for Emergency Response
  - Pedestrian, Bicyclist and Wheel Chair Detection and Collision Avoidance on Local Parallel Streets
- Fiber Optic Communication – Devices along the roadway would be connected through a network and transmit data to a central location.
- High Visibility Pavement Markings – Vehicles with automation capabilities use pavement markings for guidance and enhanced markings would improve accuracy.
- Increased Roadway Maintenance – Maintaining excellent road conditions and removing debris would reduce interference for automated vehicles and transit vehicles using shoulder lanes.
- Transit Vehicle Assist and Automation – Adding automated driving functions to transit vehicles would potentially reduce the width required for buses operating on the shoulder lanes.

## Active Traffic Management

This package of improvements would provide technology to collect data and communicate with drivers to maximize the efficiency of the roadway. These technologies would initially use a combination of roadside digital signs and in-vehicle messages, but eventually would fully transition to in-vehicle communication technologies as more vehicles are equipped. Adaptive ramp metering would be used to control the flow of vehicles entering I-680. These improvements were assumed to be implemented between the Benicia Bridge and SR-84 and would involve a cooperative, multi-jurisdictional planning process throughout the corridor.

- Vehicle Detection and Surveillance – A combination of sensors and cameras along the roadway would monitor vehicle speeds and provide real-time information on traffic flow and incidents to the traffic management center.
- Driver Information System – Drivers would receive information on advisory speeds, notices on traffic conditions, queue warnings, lane closures and construction activities.
  - Queue Warnings
  - Speed Advisories
  - Travel Times
  - Park-and-Ride Space Availability
- Dynamic Lane Use Management – The number of open lanes would be adjusted based on traffic data and inputs from the traffic management center, for example during construction or an incident.
- Adaptive Ramp Metering – Traffic signals on ramps would dynamically control the rate vehicles entering the freeway based on real-time traffic conditions and historic data. The system would be integrated with adjacent arterial traffic signal operations to optimize the

flow of the freeway while preventing backups to the adjoining roadways. Authorized transit, emergency and police vehicles would be able to receive an earlier green light or bypass ramp meters, in some cases. Ramp meters could also be coordinated with transit vehicles operating in the auxiliary and shoulder lanes to create gaps for buses approaching on-ramps.

- Integrated Information Management System – A network of computer systems would process data from the roadway (and from connected vehicles) and allow management of the ramp meters and driver information systems. Roadside cameras would provide visual information to traffic management staff. Data from the management system could be shared with emergency/incident response teams.

In addition to improvements in technology, increased incident response was assumed to be provided. Up to two additional roving tow trucks, provided by the Bay Area Freeway Service Patrol, would be dedicated to the corridor.

## Demand-Responsive Transit Service (Connected Shared Autonomous Vehicles)

Connected Shared Autonomous Vehicles (CSAVs) are self-driving (Level 4) electric vehicles designed to travel on local roadways at speeds less than 25 miles per hour. In the I-680 corridor, the vehicles would provide demand-responsive service between park-and-ride locations, residences and employers. The service would be requested using a computer, smart phone, or at consoles placed at park-and-ride mobility hub locations.

- CSAV Fleet and Operational Environment – The electric shuttles would have a capacity of 12 passengers (6 seating and 6 standing) and would operate at speeds up to 25 mile per hour. The vehicles would be capable of operating on various local streets and in commercial areas. It was assumed that 12 vehicles would be procured initially, with two vehicles serving each of six park-and-ride lots, as identified in the Enhanced Bus package.
- CSAV Hub/Docking Station – The vehicles would drop off and pick up passengers at park-and-ride locations along the corridor. These areas would also serve as locations for battery charging and light maintenance/cleaning. Consoles would be placed at the hubs to enable people to request vehicles without using a smart phone.
- Sensor and Communications – The vehicles would be capable of sensing their environment and navigating without human control. This would be accomplished through multiple sensors and communication technologies to ensure safe and accurate navigation.
- Advanced Control Systems –Advanced control systems would interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage and prioritize safety.
- Innovative Business Models – The technology and services offered by the vehicles would have the potential to create new business models for demand-driven transit with a

mixture of fixed-route transit service for communities along the I-680 corridor and private-sector services such as Uber or Lyft.

## Estimated Cost

The cost estimates for the recommended option are presented in **Table 9**. These are planning-level estimates, and the individual components could vary. The recommendation could be implemented as a program with bus service, infrastructure and technology added or modified over time.

**Table 9: Estimated Costs for Recommended Investment Strategy**

| Package | Capital Construction and Vehicle Costs | Annual Operations and Maintenance |
|---|---|---|
| Enhanced Bus Service | $71 - $76 M | $18 - $20 M |
| Connected and Automated Vehicle Support | $38 - $44 M | $1.2 – $1.4 M |
| Active Traffic Management | $101 - $104 M | $3.1 - $3.4 M |
| Demand-Responsive Transit (CSAVs) | $5 - 6 M | $0.2 - $0.3 M |
| Total Cost | $215 - $230 M | $22.4 – $24.7 M |

## Estimated Travel Time Impact

The estimated travel times after implementation and the expected change from existing is shown in **Table 10**. The transit travel time reduction is largely a factor of reduced waiting and transfer times due to the assumed frequent service. The in-vehicle travel time changes are expected to be similar to the HOV and Express modes.

**Table 10: Estimated Travel Times for Recommended Investment Strategy**

| Travel Mode | Before (minutes) | After (minutes) | Change (minutes) |
|---|---|---|---|
| Danville to San Francisco | | | |
| SOV | 66 | 61 | -5 |
| HOV & Express | 56 | 53 | -3 |
| Transit | 81 | 63 | -18 |
| Bay Point to San Ramon | | | |
| SOV | 75 | 69 | -6 |
| HOV & Express | 57 | 53 | -4 |
| Transit | 65 | 53 | -12 |
| Walnut Creek to Dublin | | | |
| SOV | 35 | 28 | -7 |
| HOV & Express | 25 | 20 | -5 |
| Transit | 47 | 32 | -15 |

## Comparison with Evaluation Criteria

The following is a summary of the recommended option compared with the evaluation criteria used for the top priority option.

- Capital and Operating Costs: The estimated cost for the recommended investment option is between $215 and $230 million in capital construction and vehicle costs. The annual operating and maintenance cost is estimated at $22.4 - $24.7 million.
- Travel Time Impacts: Depending on the trip length on I-680, the time savings vary from 5 to 7 minutes for single-occupant vehicles, 3 to 5 minutes for vehicles using the HOV express lanes and 12 to 18 minutes for transit users. The majority of the transit time savings were due to reduced wait and transfer times due to more frequent service.
- Potential Mode Shift: The estimated transit ridership was approximately 2,300 to 2,800 daily boardings, which would improve the transit mode share in the corridor.

- Markets Served: The shuttle service would primarily serve traditional commute trips in the corridor during peak periods. In addition, the expanded local and school service would improve access to local trips. In addition the use of demand-responsive transit would serve the traditional and reverse commute markets, and the mobility hubs at the park-and-ride locations would improve access to transit overall.
- Connectivity: The recommended investment would improve connectivity in the corridor, especially through integration of various travel modes across jurisdictions.
- Construction Impacts: Construction impacts from CV/AV and ATM implementation are expected to be minimal because equipment would mostly be placed along the roadside. The addition of shoulders, auxiliary lanes and potential ramp reconfiguration would likely have a temporary impact on local and freeway traffic. Construction of the park-and-ride lots would also have a temporary impact.
- Potential Environmental Impacts: No negative long-term impacts are expected.
- Conflicts with Other Traffic: The recommended investment should have an overall positive impact on traffic, especially with improvements to ramp metering to optimize traffic flow on the freeway and minimizing backups to local arterials.
- Constructability Issues: The physical infrastructure is fairly standard, and the main constructability issues will be the systems integration with the new communication technologies to ensure seamless operation. The additional bus shuttle service may require operational or infrastructure changes at BART stations to accommodate increased vehicle and passenger volumes.

## Connections with the Regional Transportation System

The recommended investment option would build upon existing and emerging technologies and provide opportunities for greater integration of the transportation system, including collaboration with private transportation providers. **Figure 5** shows a conceptual diagram of end-to-end trip. Starting at the trip origin, a person would have several options to access a Smart Mobility Hub: taking a local bus, driving alone, biking, walking, or potentially using a Connected Shared Automated Vehicle. **Figure 6** shows the potential connections to the Smart Mobility Hub.

At the Hub, the person would be able to board a shuttle that connects directly with a BART station. Alternatively, the person may be able to access another form of transportation to reach their final destination, such as an employer shuttle or a ridesharing service. Passenger information at the Hub would allow people to choose their mode according to their priorities.

In the case of using the shuttle to access BART, the person would have a reliable connection to the regional rail system using the shoulder and auxiliary lanes to bypass congestion on I-680. At the BART station, the person would have travel options in addition to using the BART service. For example, the person may walk to a destination near the station or connect with a local or regional bus service. Using BART, the person would be able to travel to a station outside of the corridor. Upon arrival at the BART station near their destination, the person would have a new set of options to reach their final destination.

**Figure 5: Conceptual Trip Using Collections Points**

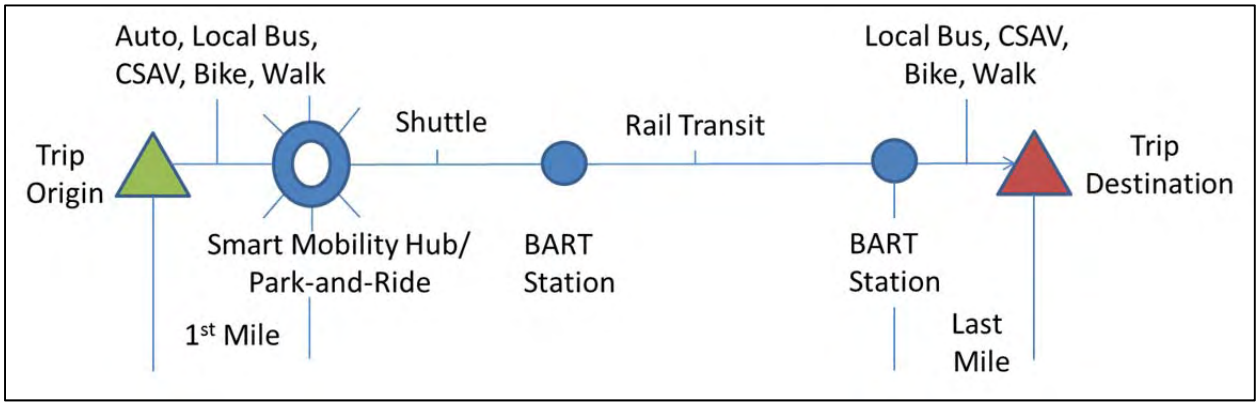
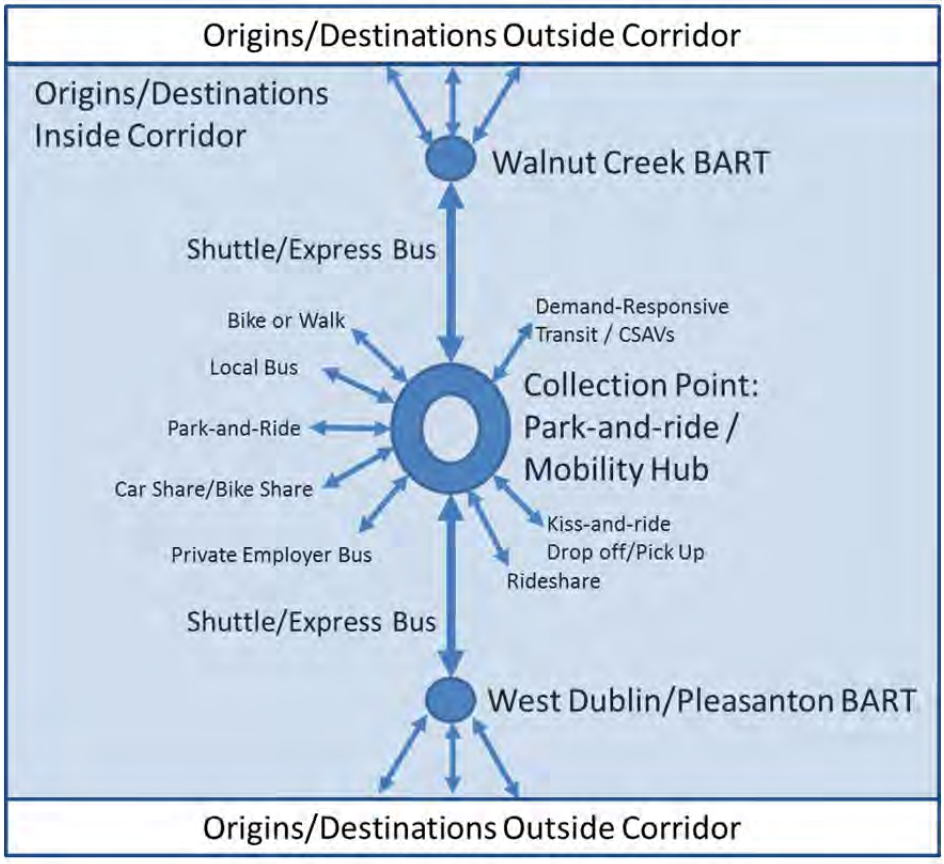



**Figure 6: Connection Point Hub and Spoke Model**



# 6 NEXT STEPS

The I-680 Transit Investment/Congestion Relief Options Study has produced a recommended investment package for the I-680 corridor. This recommendation will improve transit service and capacity while also improving the operation of the freeway and reducing congestion. The recommended investment strategy will build on the progress made with previous investments in transit services in the corridor. It will also take advantage of the significant advancements in communications, vehicle automation and transportation system management that are changing how people will travel and interact with each other in the future. The investment package has been defined at a high conceptual level. Before this investment can be made, however, a more detailed evaluation of the recommended investment package should be conducted. This should include more detailed evaluation of potential ridership and revenue, capital and operating costs, technology requirements, interagency coordination requirements, and environmental impacts, and funding opportunities. This additional evaluation will be needed to specify the details of the investment strategy and produce the final design for its individual elements.

## Project Implementation

The recommended investment option package includes a combination of capital and operational improvements. The steps needed to realize implementation of these improvements vary somewhat as a function of the type of improvement, location, and affected jurisdictions, although in all cases a critical step will be that of securing the necessary funding.

For capital improvements to the freeway, additional steps will likely include coordination with Caltrans and preparation or amendment of Caltrans documents such as a Project Initiation Document (PID) and documents associated with the Project Approval and Environmental Document (PA/ED) phase. Ultimately implementation will also include detailed design and acquisition of right-of-way (as necessary). In the execution of these steps, specific implementation issues may be identified and need to be resolved. One issue that will need to be addressed is that the use of freeway shoulders by buses to bypass congestion in the mixed flow lanes conflicts with current Caltrans policy. Implementation steps for this element would have to include advocacy for a change in policy and potentially changes in legislation.

For new shuttle, local and express bus service, steps may include defining specific service requirements, purchasing vehicles, and modifying maintenance facilities as needed. Coordination with BART would also be needed to ensure that shuttles operate efficiently at the BART stations and that sufficient capacity is provided for the additional passengers. Implementation steps for the new park-and-ride lots and Smart Mobility Hubs include determining specific park-and-ride locations and space requirements, and negotiating lease agreements with affected parties. Planning for the park-and-ride locations would also include consideration of options to reduce the footprint of the parking area and/or reducing the time to park. These options may include structured parking, valet parking, automated or mechanical parking systems, and dedicated areas for passenger pick-up and drop-off and/or private transportation services.

Many aspects of the recommended investment package are designed to take advantage of and support technology advancements that are still under development. This specifically relates to

the support of Connected Vehicle/Automated Vehicles Support elements and the Demand-Responsive Transit Service (Connected and Shared Automated Vehicles - CSAV) elements. Both are designed to support technology advancement that will increase the efficiency and safety of travel and reduce the cost by allowing automated operation of vehicles. Implementation of these elements in the corridor will require the design and implementation of the detection, communication, and control systems necessary to manage the operation of vehicles and the dissemination of driver information. It will also require interagency agreement on how the necessary infrastructure and management systems will be designed and implemented and who will operate the systems. Pilot testing of the CV/AV and CSAV technologies will also need to continue to ensure that the technologies are sufficiently developed before there is large-scale implementation in the corridor.

Implementation of the Active Traffic Management elements would require a collaborative process between MTC, Caltrans, CCTA, Alameda CTC, the jurisdictions along the corridor and the transit operators providing bus services in the corridor to ensure that the technologies and management systems will support an interjurisdictional, integrated, and multimodal system for managing the traffic flow in the corridor and support all of the transportation programs in the corridor. In addition to the elements of the recommended investment strategy form this study, the system should also recognize and support the Express Bus system, the HOV and Express Lane system, and the Freeway Service Patrol system. Specification and design of the elements of the Active Traffic Management portion of the investment package could follow a process much like that used in I-80 corridor where most of the same agencies were involved.

## Funding

One of the primary objectives of this project was to identify an investment package for the I-680 corridor that could be included in a Transportation Expenditure Plan for a possible sales tax renewal should the CCTA Board decide to move forward with a sales tax renewal measure in 2016. Having identified the "Enhanced Bus and Innovative Transportation Systems Package" as the preferred option, the remaining steps to ensure that the proposal is considered in a potential Measure J Reauthorization are:

- Present study results to TVTC, SWAT and TRANSPAC for consideration;
- Request that TVTC, SWAT and TRANSPAC include the preferred option in their investment priorities for CCTA to consider in the reauthorization; and
- Assuming that the proposal is included as a candidate project for the reauthorization, develop a financial plan for the project and conduct more detailed analysis/design of the different components of the package.

Although the I-680 Transit Investment/Congestion Relief Options Study was funded by CCTA, the study corridor included portions in Alameda County and the PAC and the TAC for the project included representatives from Alameda County jurisdictions as well as Contra Costa County jurisdictions. Funding for the portions of the investment package in Alameda County would have to come from programs included in the Transportation Expenditure Plan for the sales tax extension past in Alameda County in 2014 or from other sources. Funding for elements

of the investment package in either county could also come from regional funds distributed by MTC or from state or federal funding programs. A listing of possible sources and the elements of the recommended investment package for which they might be relevant is provided in **Table 11.**

**Table 11: Potential Funding Sources**

| Potential Funding Sources for I-680 Transit Investment/Congestion Relief Options Study | | | | | | |
|---|---|---|---|---|---|---|
| **Funding Source** | **Potential Application** | | | | | |
| | Park-and-Ride Lots | Bus Service Improvements | Connected and Shared Automated Vehicles | Smart Mobility Hubs | Connected and Automated Vehilces | Active Traffic Managment |
| County Sales Tax Measures | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Community Development Block Grant Program (CDBG) | ✓ | | | | | |
| Congestion Mitigation and Air Quality Improvement Program (CMAQ) | ✓ | ✓ | ✓ | ✓ | | ✓ |
| DD-104 (Deputy Directive): Creating New Opportunities for Solar Energy Systems Deployment | ✓ | | | ✓ | | |
| Environmental Enhancement and Mitigation Program (EEMP) | ✓ | | | | | |
| FTA Capital Program (Section 5309) | | ✓ | | | ✓ | |
| FTA Urbanized Area Formula Program (Section 5307) | ✓ | ✓ | ✓ | ✓ | | |
| Low Carbon Transit Operations Program (LCTOP) | | ✓ | ✓ | ✓ | | |
| Transportation Development Act (TDA) - LTF and STA | ✓ | ✓ | ✓ | ✓ | | |
| Public Private Partnerships - MTC regional pilot program or independent approach | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Regional Surface Transportation Program | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| State Highway Operation Protection Program | ✓ | | | | | |
| State Transportation Improvement Program (STIP) | | ✓ | | ✓ | | ✓ |
| Transit and Intercity Rail Capital Program (TIRCP) | | ✓ | ✓ | ✓ | | |
| One Bay Area Grant Program | ✓ | ✓ | | ✓ | | |
| Local Jurisdiction Impact Fees | ✓ | | | ✓ | | |

# Appendix A
# Maps of Top Priority Options

**Figure 7: Map of Potential Park-and-Ride Locations**

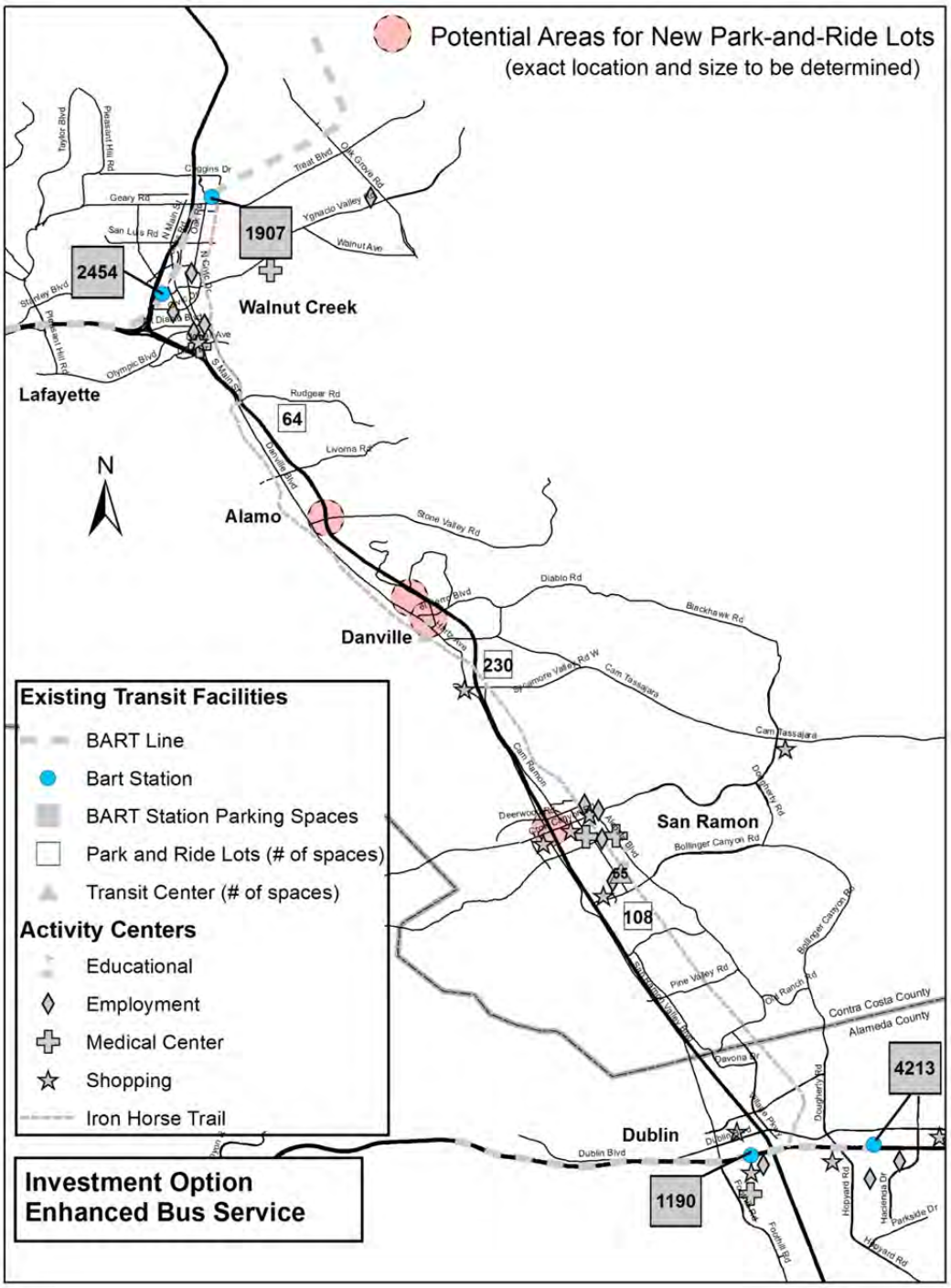


**Figure 8: Map of Elevated Tram Option**

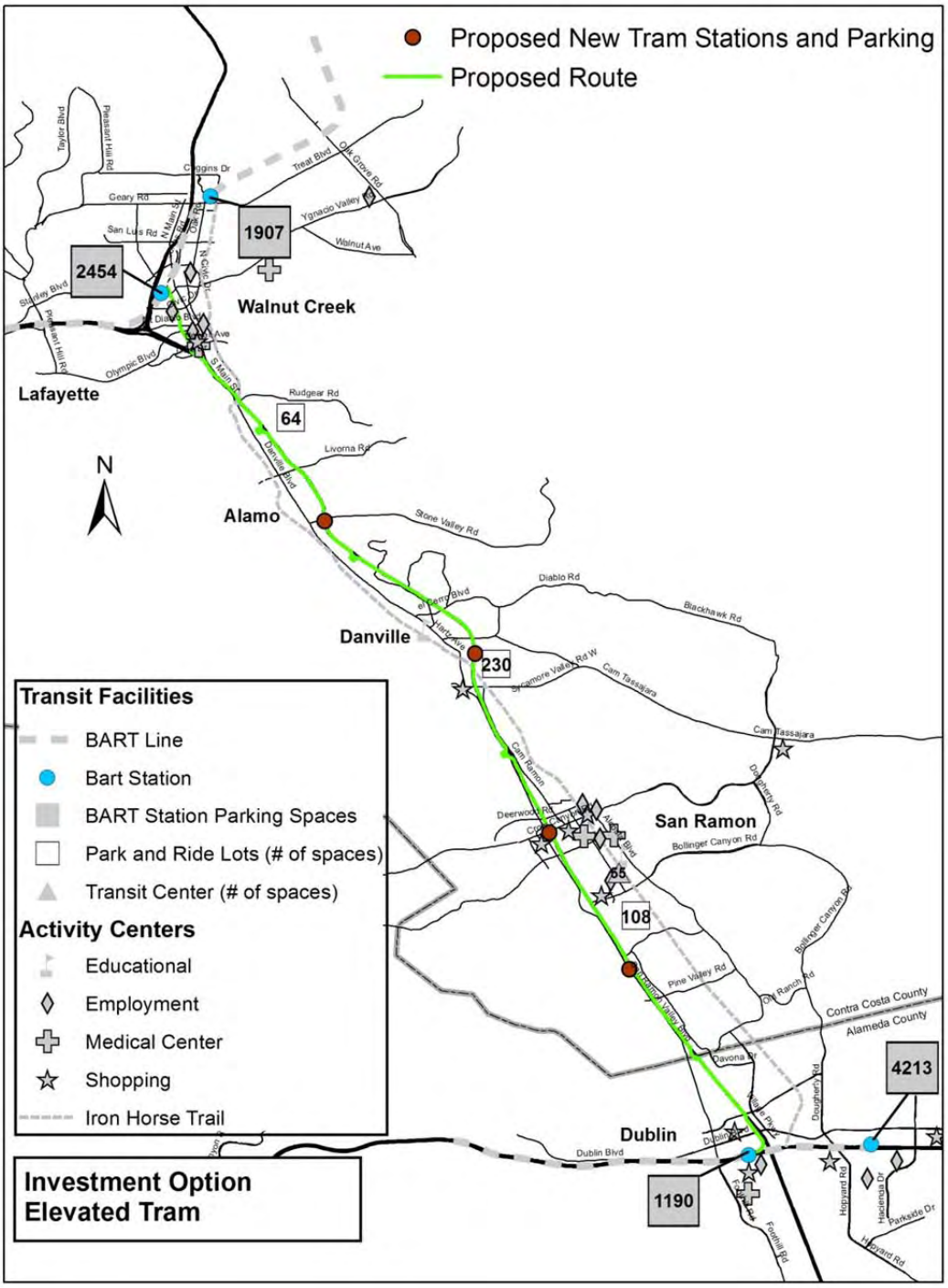


**Figure 9: Map of BART Option**

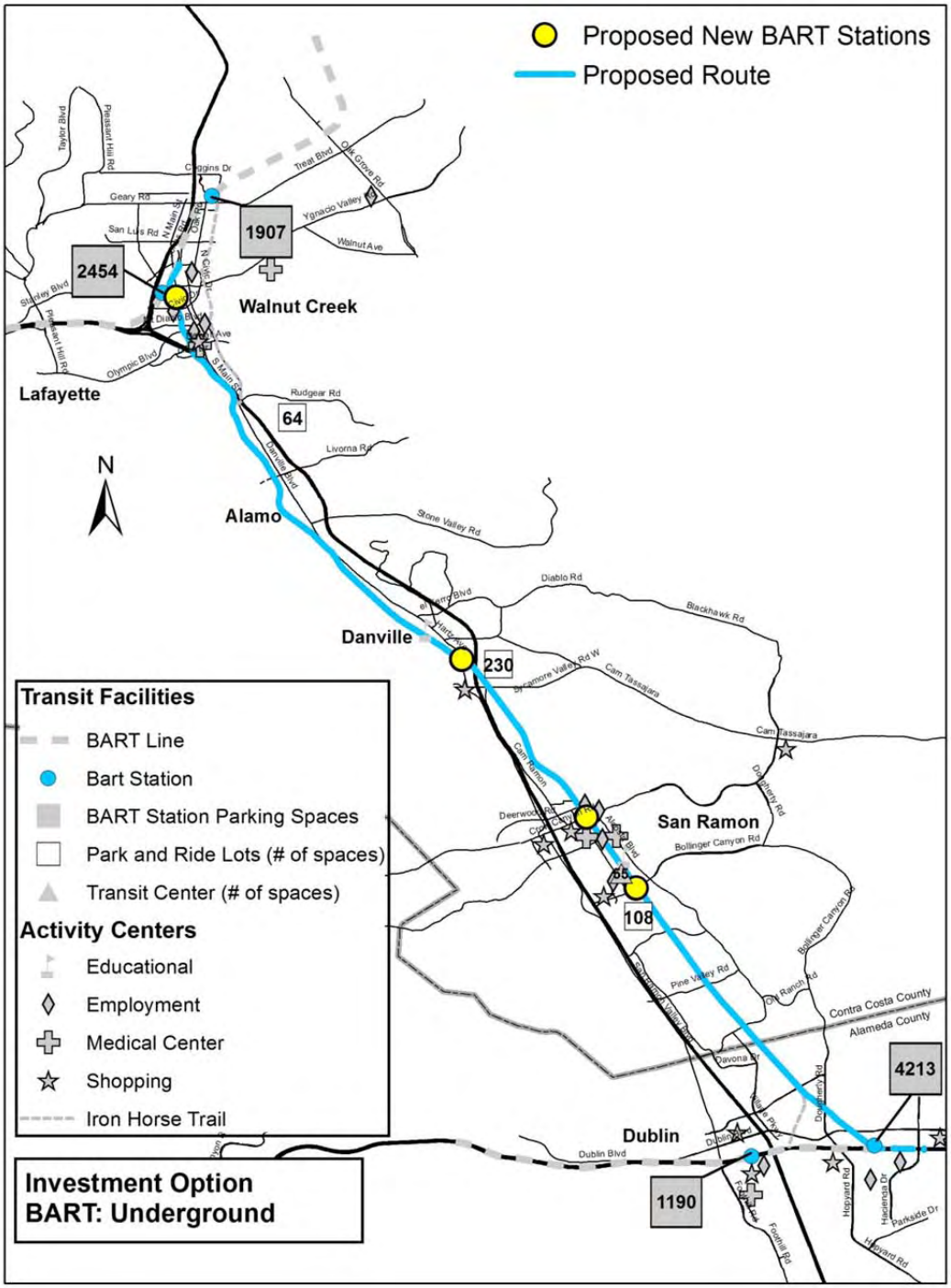


**Figure 10: Map of Alternate Rail Alignments**