Bay Bridge Corridor Congestion Study

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Summary

The Bay Bridge Corridor Congestion Study estimates the future operating conditions for vehicles traveling across the Bay Bridge from Oakland into San Francisco during the peak morning commute hours. The study utilizes a microsimulation model to analyze a 24-mile freeway network that includes the Bay Bridge, the toll plaza and metering lights in Oakland, the distribution structure ("MacArthur Maze"), and segments of Interstates 80 (I-80), 580, and 880. The study predicts the severity of future vehicle queuing at the toll plaza and assesses how this congestion could affect bus service between the East Bay and the new Transbay Transit Center (TTC).

The analysis indicates that future traffic growth along the corridor will result in a substantial worsening of congestion at the Bay Bridge toll plaza. The projected queues would block the High Occupancy Vehicle (HOV) lanes that currently serve as a bypass around the toll plaza for Transbay buses. These future conditions would result in a significant degradation to transit operations.

To improve operating conditions along the corridor, a series of potential operational and physical improvements are evaluated. These improvements include the implementation of a westbound contraflow lane along the Bay Bridge during the morning commute and various options for accessing the contraflow lane on the Oakland and San Francisco sides. A contraflow lane incorporates a reversible travel lane. In this study, a westbound contraflow lane across the Bay Bridge in the morning would utilize the leftmost travel lane that typically serves eastbound traffic. The analysis indicates that a contraflow lane, in conjunction with a series of other roadway improvements, could help maintain future transit reliability. Conceptual cost estimates and the feasibility of these improvements are also discussed.

The study also considers conditions for the eastbound return trip that originates in the "South-of-Market" (SoMa) district of San Francisco during the afternoon commute. While traffic heading into San Francisco in the morning can queue on freeway lanes approaching the toll plaza in Oakland, traffic exiting San Francisco using the Bay Bridge must queue on local SoMa streets during the afternoon. This queuing can have a negative effect on local transit and traffic operations in San Francisco. For this evaluation, a microsimulation model of 75 intersections within the local SoMa street network was developed. The SoMa model incorporates dynamic assignment, which allows traffic to reroute as congestion builds within the simulation model. A base year calibrated network was developed and several potential improvements to the Bay Bridge on-ramps were investigated. This analysis suggests that the on-ramp changes have local and regional benefits, but further work is required. The effort is intended as a "first-step" towards a more detailed study of these potential improvements.

Enhancing transportation operations and capacity along the Bay Bridge corridor is critical for the following reasons:

- The performance of the new TTC is dependent on maintaining reliable and convenient bus links with the East Bay
- The existing travel demand between the East Bay and San Francisco is approaching the capacity of the available transportation modes (auto, bus, rail, ferry)
- The economic viability of downtown San Francisco, including additional development planned for the SoMa area, is dependent on increasing transportation capacity with the East Bay

The results of the study are intended to provide a point of discussion for policymakers as improvement options are considered in the corridor.

Figure 1: Bay Bridge Corridor Study Area

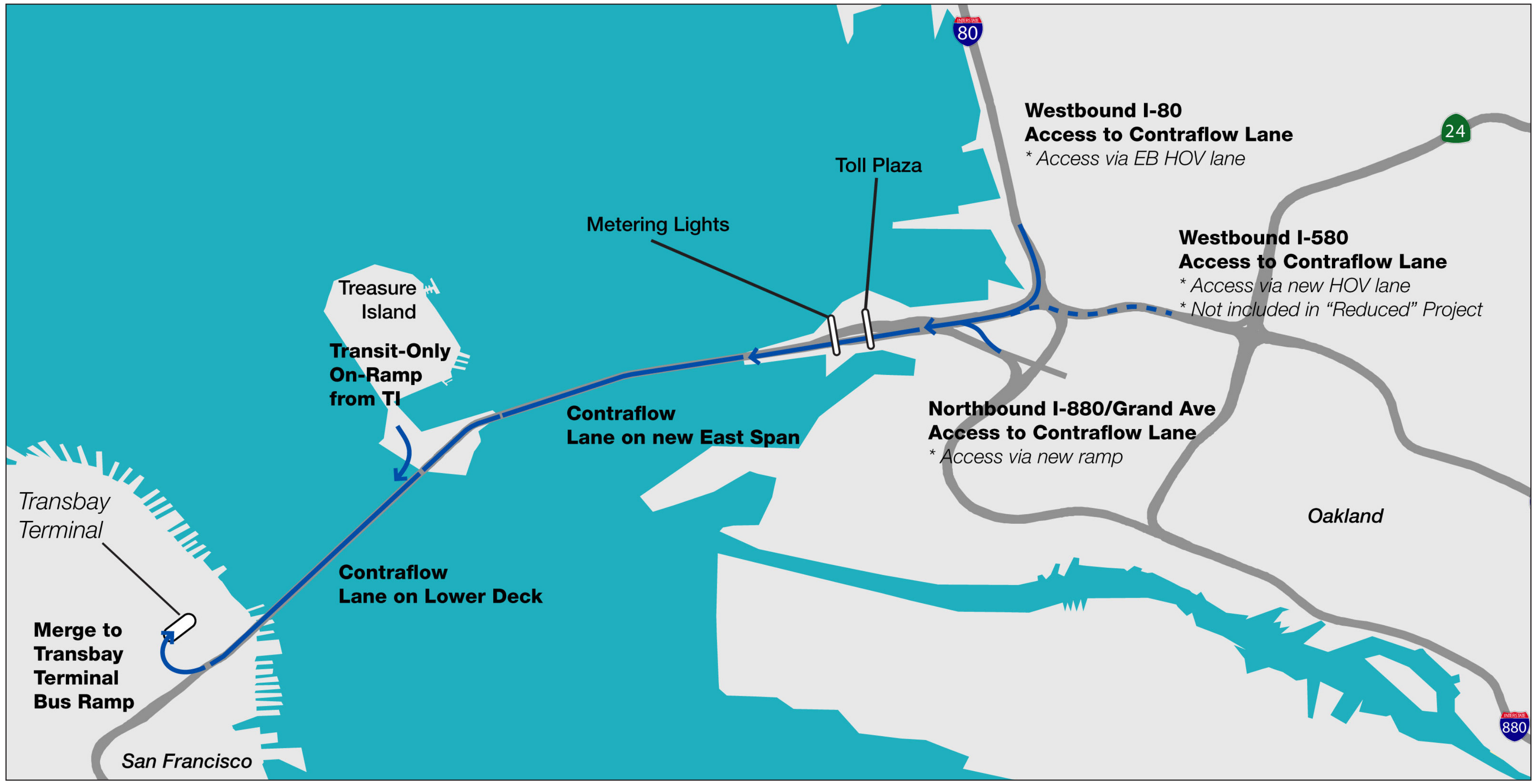


Figure 2: Improvement Options

Model Development

A transportation microsimulation model was developed for a 24-mile study area using the software program VISSIM. Figure 1 presents the study area included in the westbound AM VISSIM model.

The model study network includes fifteen freeway interchanges serving the westbound direction into San Francisco. The VISSIM model was calibrated to October 2009 conditions at the Bay Bridge toll plaza and the metering lights. The calibrated VISSIM model was used as a basis for the future operations analysis.

Improvement Options

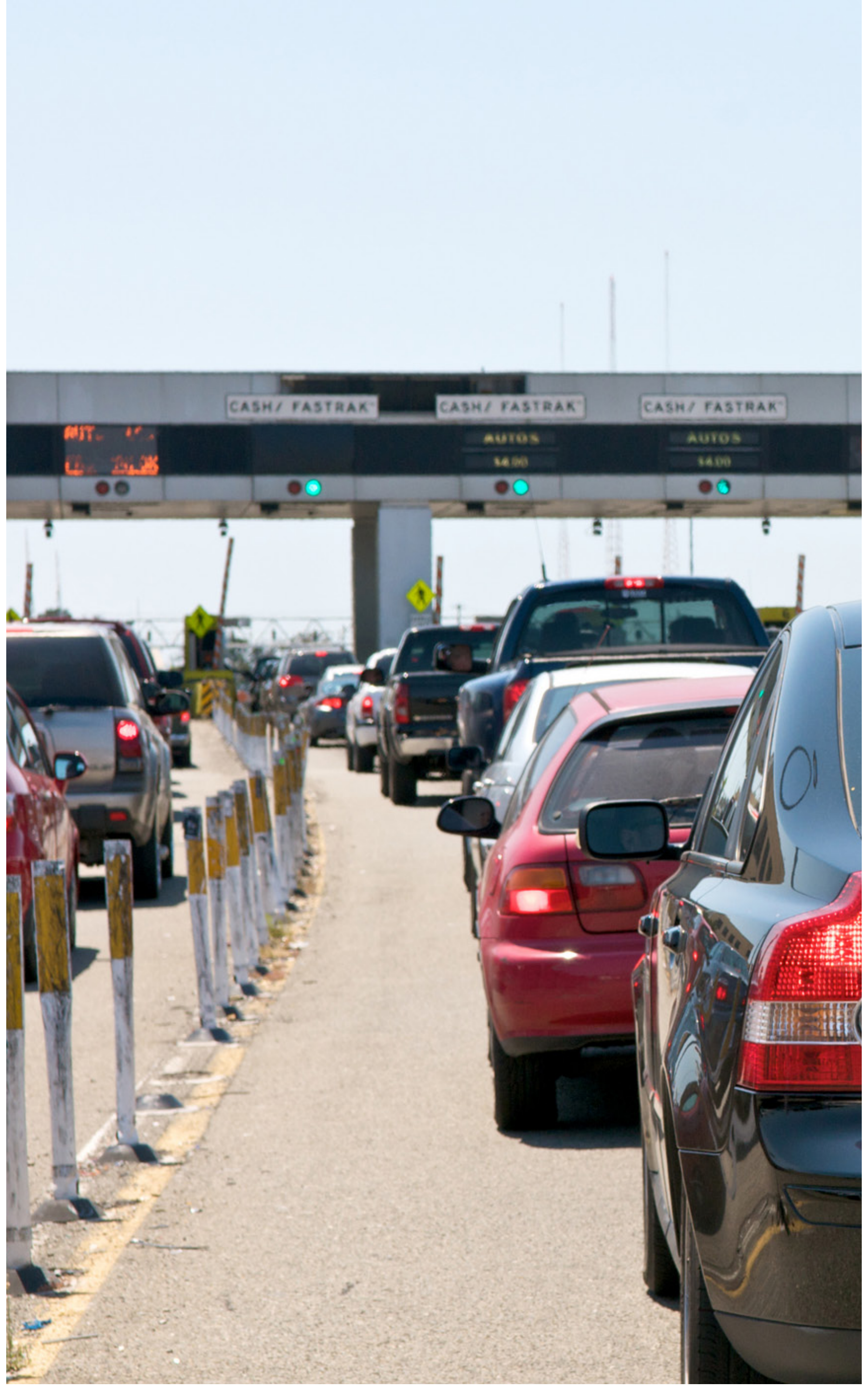
The analysis considers two different approaches to improving operations along the westbound Bay Bridge corridor during the morning commute:

1. **Alternative Metering:** Increase the metering rate at the Bay Bridge metering lights to shift the queue on to the bridge and reduce the likelihood of vehicles blocking the HOV bypass lanes.

2. **Physical Improvements:** A package of physical improvements that include a westbound contraflow lane on the Bay Bridge, access points necessary to enter the contraflow lane on the East Bay side and exit the contraflow lane on the San Francisco side of the bridge, and extension of the HOV network in the vicinity of the toll plaza.

Figure 2 shows the package of proposed physical improvements. The contraflow lane could be operated as a bus/high occupancy toll (HOT) facility or as a bus/truck facility.

Summary



Analysis Scenarios

A series of analysis scenarios was developed to assess future operating conditions along the corridor. These scenarios were developed using the calibrated VISSIM model, the improvements listed above, and future 2035 baseline traffic forecasts obtained from the San Francisco County Transportation Authority's (SFCTA) travel demand model (SF-Champ). Existing bus service within the corridor was obtained from current schedules, while future bus service assumptions were developed from TTC planning studies and are based on total TTC capacity. Table 1 summarizes the analysis scenarios:

Scenario	Assumptions
Base Year	• October 2009 traffic volumes and existing bus frequencies • October 2009 roadway network
Future 2020 No Improvements	• 2020 traffic volumes interpolated from 2035 SFCTA travel demand model and 2035 bus frequencies • No changes or improvements to the roadway network
Future 2035 No Improvements	• 2035 traffic volumes and bus frequencies • No changes or improvements to the roadway network
Future 2035 With Alternative Metering	• 2035 traffic volumes and bus frequencies • Increased metering rate, no changes to the network
Future 2035 With Physical Improvements	• 2035 traffic volumes and bus frequencies • Full set of physical improvements, no metering change • Assumes contraflow lane operates as a HOT lane with 1,000 vehicles per hour
Future 2035 With Reduced Set of Physical Improvements	• 2035 traffic volumes and bus frequencies • No I-580 HOV lane, no metering change • Assumes contraflow lane operates as a HOT lane with 1,000 vehicles per hour

Table 1: Analysis Scenarios

Performance Measures

Performance measures and targets were established by the consultant team in consultation with the stakeholders in the study. The performance measures are grouped into three categories: congestion, transit travel time, and transit reliability. A set of targets is defined for each measure. The performance measures and targets for the westbound Bay Bridge corridor analysis are:

- **Congestion**
  - The length of the Toll Plaza queue should not extend beyond the distribution structure
  - Total vehicle-hours of delay and person-hours of delay in each 2035 improvement scenario should be less than the 2020 and 2035 No Project condition
- **Transit Travel**
  - Transit speeds should average not less than 42 miles-per hour (mph) between the distribution structure and the TTC
  - Notes: The distance from the distribution structure to the TTC is approximately seven miles. A bus traveling at 42 mph will cover this distance in about 10 minutes.
- **Transit Reliability**
  - No individual peak period transit trip should exceed 14 minutes between the distribution structure and the TTC.

The performance measures and targets were evaluated for each scenario based on the results of the microsimulation modeling. Table 2 provides a summary of these results for the 8-9 AM hour. Table 2 indicates whether the target is satisfied – "Pass" – or exceeds the target – "Fail".

The results in Table 2 indicate that the westbound AM corridor would experience acceptable operating conditions through 2020. However, the analysis predicts that conditions for both transit and autos would degrade to unacceptable levels by 2035. The two Physical Improvement scenarios could substantially improve mobility through the corridor, particularly for transit. The results indicate that the physical improvements examined in this study have clear operating benefits.

Summary

Performance Measures (8-9AM) Summary							
Category	Measure	2009 Base Year	2020 No Project Target Met?	2035 No Project Target Met?	2035 Alternative Metering Target Met?	2035 With Physical Improvements Target Met?	2035 With Reduced Set of Physical Improvements Target Met?
Congestion	Toll Plaza queue - Not Beyond Dist Structure	Pass	Pass	Fail	Pass	Pass	Pass
	Total Vehicle Hrs of Delay	2,350	2,725	3,208	3,680	2,168	2,288
	Chg from 2009 Base Year (%)	N/A	16%	37%	57%	-8%	-3%
	Chg from 2035 Base Case (%)	N/A	N/A	N/A	15%	-32%	-29%
	Total Person Hrs of Delay	3,583	3,937	4,720	6,256	3,254	3,426
	Chg from 2009 Base Year (%)	N/A	10%	32%	75%	-9%	-4%
	Chg from 2035 Base Case (%)	N/A	N/A	N/A	33%	-31%	-27%
Transit Travel	Transit speeds should average not less than 42 mph (measured from I-80)	47 mph = Pass	46 mph = Pass	37 mph = Fail	27 mph = Fail	53 mph = Pass	53 mph = Pass
Transit Reliability	No individual peak period transit trip should exceed 14 minutes (measured from I-80)	11.5 min = Pass	12 min = Pass	15 min = Fail	20 min = Fail	10 min = Pass	10 min = Pass

Table 2: Performance Measures

Review and Conclusions

San Francisco employment is projected to increase by about 50 percent over the next 25 years. Already 40,000 workers commute into the city from the East Bay in the peak hour; simply projecting a 50 percent increase beyond the current use will create demand beyond the peak hour capacity of the Bay Bridge and BART.

The study used several analysis tools including:

- A detailed microsimulation model of the AM peak period commute testing a range of improvements, including alternative toll plaza metering and physical projects. The physical improvements included a westbound bus contraflow lane on the Bay Bridge that could operate as bus/HOT lane or a bus/truck lane; other improvements included new ramps to enter and exit the contraflow lane, as well an extension of the HOV network in the East Bay.
- A detailed microsimulation model of the SoMa area in downtown San Francisco studied PM peak period conditions on local streets that serve afternoon commute traffic accessing the eastbound Bay Bridge.

The major conclusions of the Bay Bridge Corridor Congestion Study are:

AM Westbound

- The Bay Bridge and the toll plaza are currently are congested on most days; however, vehicle queues do not typically extend back from the toll plaza to the distribution structure.
- The HOV bypass lanes are not typically blocked, which allows for acceptable bus operations.
- With projected increases in traffic along the corridor, queuing will worsen and routinely block the HOV bypass lanes in the future.
- Transbay buses will not meet transit performance targets by 2035, which will limit the performance of the Transbay Transit Center.
- The physical improvements show considerable promise for maintaining bus travel times and schedule reliability along the corridor, while also providing potential increases in person-trip capacity

PM Eastbound/SoMa

- Based on a preliminary analysis of the SoMa area, a reconfiguration of the Bay Bridge on-ramps and streets feeding these ramps could result in both improvements in regional access to the Bay Bridge and a betterment of local circulation for transit.
- SoMa traffic is impacted by the land configuration of the eastbound West Approach and Bay Bridge.
- The SoMa model development has produced a valuable tool for future study of the area

Overall, the study has identified existing and future constraints along the corridor, developed tools to effectively analyze improvement options, and generated ideas that warrant further study

Introduction

The Challenge

The Association of Bay Area Governments (ABAG) forecasts that San Francisco employment will increase by approximately 240,000 (about 50%) by 2035. The traditional downtown job centers, the Financial District and the "South-of-Market" (SoMa) area, will add more than 100,000 of these jobs. Another 50,000 jobs could be added along the US-101/Bayshore corridor in Priority Development Areas designated by San Francisco and ABAG. To the immediate south of the San Francisco-San Mateo County Line, Brisbane, South San Francisco and the San Francisco International Airport area are projected to add almost 40,000 jobs. Many of these job centers are not located in transit-rich corridors.

Traditionally, East Bay residents have filled about 40 percent of the jobs in downtown San Francisco, 15 percent of the jobs in the 101/Bayshore Corridor, and 5 percent of the jobs in the South San Francisco and Brisbane area. This pattern that will likely continue as population growth in the City is projected to be less than the increase in jobs (160,000 new residents versus 240,000 new jobs).

Already 40,000 workers commute into the city from the East Bay in the peak hour; simply projecting a 50% increase beyond teh current use will create demand beyond the peak hour capacity of the Bay Bridge and BART. However, the Bay Bridge is already at capacity and commuter rail service offered by the San Francisco Bay Area Rapid Transit District (BART) has capacity for only 8,000 to 12,000 additional trips per hour. The new Transbay Transit Center (TTC) will provide additional Transbay capacity on a new and expanded bus deck. However, bus operators are concerned that future traffic growth may compromise the operations of the HOV lanes that allow buses to bypass queues at the Bay Bridge toll plaza. It is likely that demand for job access to transit-deficient locations on U.S. 101 will also compete with existing automobile access to San Francisco. These forecasts suggest that the transportation capacity into San Francisco from the East Bay will not support the level of expected development and could have negative quality-of-life impacts.

In the SoMa area, the local street system often gridlocks with afternoon commute traffic bound for the Bay Bridge. While traffic heading into San Francisco in the morning can queue on freeway lanes approaching the toll plaza in Oakland, traffic exiting San Francisco must queue on the local SoMa streets. Currently, traffic demand from the Financial District and SoMa job centers greatly exceeds the capacity of the Bay Bridge on-ramps in the afternoon. The forecast increase in jobs and residents in downtown San Francisco, coupled with the corridor capacity constraints identified in the westbound AM analysis, will contribute to worsening queuing conditions on locals SoMa streets.

Study Approach

Arup was commissioned by the **Transbay Joint Powers Authority** and **AC Transit** to develop an initial study of the impacts of future demand on the Bay Bridge Corridor. **Cambridge Systematics** provided traffic forecasts and reviewed the microsimulation models. **LCW Consulting** provided analysis and oversight. The objective of the study is to:

> Develop a high-quality analysis that produces an estimate of future operating conditions for cars, trucks and buses along the Bay Bridge corridor under congested conditions. This analysis will identify potential improvement options and serve as a useful case study of corridor planning in the San Francisco Bay Area. The intent is to produce a report that the Federal Transit Administration and other project sponsors can share with planning and transportation agencies to help motivate the discussion of improving mobility along the Bay Bridge corridor.

The SoMa PM analysis considers a different study area with a different set of constraints than the westbound AM analysis. The SoMa PM component of the analysis considers a very large and complex urban grid network, which poses a series of modeling challenges. These challenges have limited the scope of the SoMa analysis presented in this study. However, a set of potential improvements are introduced and investigated.

To complete these expectations, the study's work tasks include:

1. Study of the Bay Bridge Corridor Background and Context
2. Microsimulation Model Development
3. Improvement Options
4. Future Scenario Analysis
5. SoMa Model Development and Analysis
6. Further Study

Previous Studies

The Bay Bridge corridor has been the subject of several studies dating back more than twenty years, usually under the sponsorship and direction of the Metropolitan Transportation Commission (MTC), . These studies include:

The I-80 Corridor Study, issued by MTC in 1988 and prepared with consultant assistance:

The report noted that between 1980 and 2005 workers would increase faster than jobs in the corridor (from Richmond to Solano County) and that even with more than $600 million in highway improvements, "I-80 is projected to experience severe peak hour congestion in the year 2000 from Vallejo to the Bay Bridge, due to increases in commuting." Among the projects recommended were the I-80 HOV lanes, which are now in operation. In addition, the study considered an I-80 "Bus Facility" to save time on the Alameda County portion of I-80 as well as the Bay Bridge (not implemented), and also additional express bus improvements and other widening, arterial and park and ride improvements. Many, but not all, of the improvements were completed, including the HOV lanes, the park and ride facilities, and the arterial (San Pablo Avenue) improvements.

San Francisco Bay Crossing Study, prepared for MTC by Korve Engineering, Inc. (1991):

In 1991, under a request from the state Senate, MTC examined 11 "build" alternatives to improve Transbay travel. These ranged from new bridges and tunnels for both cars and trains to additional ferries and airport to airport connections. The options were narrowed to five major concepts:

- High Speed Ferry Service
- I-380 to I-238 (S. San Francisco to Hayward) Bridge with BART
- BART SFO-OAK connection
- New BART Transbay Tube
- Intercity Rail Connection

The key findings were that:

- Planned and programmed improvements including widening the San Mateo-Hayward Bridge and more frequent BART service would provide enough capacity to accommodate Transbay travel to 2010, although congestion would increase.
- The new bridge plus BART would carry the greatest number of trips but would only reduce the duration of the Bay Bridge peak period and not the volume of the peak hour. In addition, there would be significant land use impacts and environmental impacts with new bridges or tunnel options.

San Francisco Bay Crossing Study, prepared for MTC by Korve Engineering, Inc. (2002):

About 10 years after the 1991 study, MTC (in response to a request from Senator Dianne Feinstein) studied six different alternatives for Transbay travel including a new Bridge (again between I-380 and I-238) as well as improvements to the San Mateo Bridge, west side Dumbarton Bridge access improvements, and Dumbarton rail service. A new BART/conventional rail tunnel was also considered, as well as a lower cost express bus and HOV system improvements. The express bus/HOV system included additional HOV lanes, more express bus service in Transbay corridors, and additional park-and-ride lots for Transbay buses.

The key recommendations from the study's Policy Committee were that:

- Lower cost operational improvements could be implemented as a near-term response to traffic congestion in the bridge corridors. These included additional HOV lanes and Toll Plaza improvements, modest BART capacity increases, and additional express bus service.
- New crossings will be extremely costly, in some cases requiring funding equal to or exceeding the entire amotunt of new regional funds estimated by MTC's RTP to be available over the next 25 years. The report noted that a "major new Bay crossing has intrigued the public for a long time, but has not yet received a critical mass of support."
- Use existing funds to reestablish San Mateo Bridge bus service.
- Pursue new bridge toll funds (which were later approved by the Legislature and the voters in RM2) for reversible lanes on the San Mateo-Hayward Bridge, Dumbarton rail basic service, additional carpool lanes and BART core capacity improvements.

Further studies should include:

- Higher cost bridge HOV improvements (including an I-580 HOV lane and other improvements on the San Mateo and Dumbarton Bridges)
- Dumbarton approach improvements
- BART core capacity improvements
- Express bus physical improvements including HOV improvements that would benefit express buses

The detailed analysis noted that the express bus/carpool and operational improvement alternative was extremely cost effective, relative to other alternatives. This alternative included HOV lanes and spot operational traffic improvements on bridge approaches, toll plaza modifications including electronic toll collection, incremental expansion of Transbay BART service, and expanded express bus service in all three bridge corridors with park-and-ride lot expansion and additions.

The study noted that the five to six new HOV lanes or extensions near the Bay Bridge have merit, but recommended further study and analysis. The study stated that if systemwide and Transbay capacity plans that were under development by BART were implemented, projected demand for Transbay BART service could be handled by adding additional trains and pursuing strategies for faster boarding and alighting of passengers in the downtown San Francisco stations (through the use of three-door cars). The study also noted that "adequate platform space in downtown San Francisco stations may become a capacity constraint by or before 2025" and also noted that "further study is needed to refine our understanding of BART Transbay capacity constraints and needs." Some of those studies have been conducted, but few BART capacity increases have been implemented.

Bay Bridge Corridor Background

2002 HOV Lane Master Plan, prepared for MTC by DKS Associates (2002)

In 2002, MTC commissioned the HOV Master Plan, which identified the use and benefits of the HOV system and identified an overall vision for a regional HOV network. The general conclusions were that most Bay Area HOV lanes were performing within Caltrans criteria with volumes ranging from about 2,000 vehicles per hour (U.S. 101 in Santa Clara) to a midrange of about 1,300 vehicles per hour on I-80, I-880 and U.S. 101 (Marin). Some routes have fewer vehicles. In addition, the HOV Master Plan forecast additional increases in usage on most routes and forecast use of new HOV facilities.

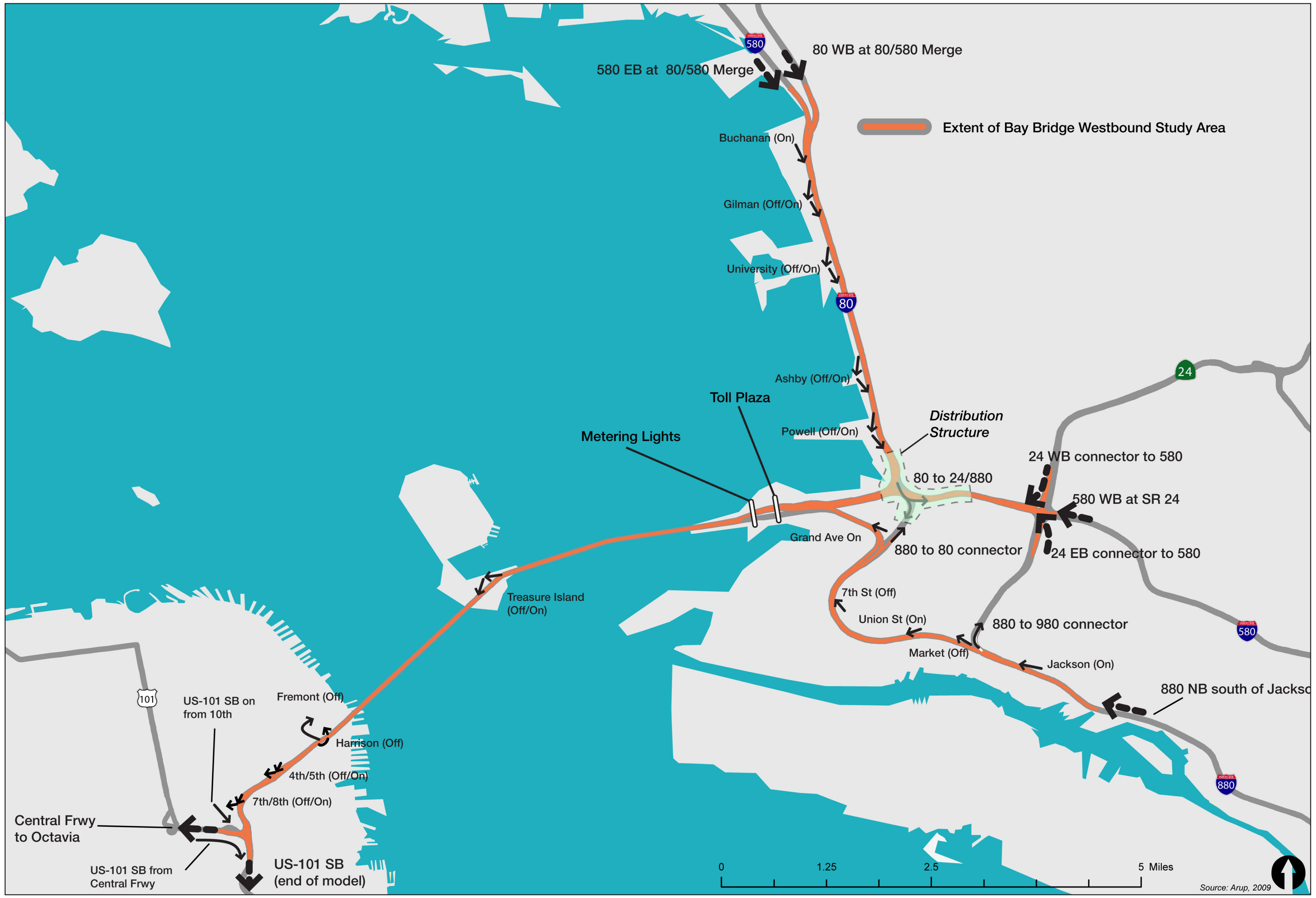
The HOV Master Plan called for an additional 300 miles of HOV lanes, costing about $3.7 billion. In addition, the Plan called for a network of express buses to use the HOV lanes, and suggested that buses be provided with in-line freeway-stations with good intermodal connections to save time, decrease operating costs and encourage ridership. The Plan also noted that some, but not all, HOV lanes had excess capacity in the present, but perhaps not in the future and HOT could be considered on some corridors. The Plan did note that there was excess capacity in all corridors in the off-peak and reverse peak periods.

Bay Area High-Occupancy/Toll Network Study, Final Report (and Update), MTC with assistance from PBAmericas and ECONorthwest, 2007 and 2008

Moving from the 2002 Bay Crossing Study and the 2002 HOV Master Plan, MTC analyzed the impacts and benefits of converting the HOV network into a HOT network. The analysis indicated that by tolling HOV facilities the network could be built earlier and could free-up programmed RTP funds to other projects. The Study noted that HOT revenues could be made available to fund express bus service in the HOT corridors.

The Future of Downtown (San Francisco), San Francisco Planning and Urban Research Association (SPUR), March 2009

SPUR produced a policy paper that compared ABAG's future year employment and population projections against both the city's development (zoning) capacity and its transportation capacity. About 40 percent of downtown San Francisco jobs are held by East Bay residents and SPUR projected that within 25 years peak hour demand from new jobholders would exceed available transit capacity (including BART and expanded bus and ferry services). Within 10 years it is likely that BART will be near capacity, although the opening of the new Transbay Transit Center represents new near-term capacity in the corridor.



Source: Arup, 2009

Figure 3: Westbound AM Study Area

Existing Transportation Context

Figure 3 shows the westbound Bay Bridge highway system that is included in the study area, with the ramps and the major gateways that make up the extents of the freeway network. The bridge, which connects Oakland with San Francisco, was opened in 1936 as a highway/rail facility. In the early 1960s the railroad on the lower deck was removed and the Caltrans converted the Bridge to five lanes of traffic in each direction, with each bridge deck carrying a one-way flow. The current "cantilever" section of the bridge, which connects the East Bay to Yerba Buena Island (YBI), is a double deck steel structure. This section is being replaced with a new concrete structure featuring a self-anchored suspension bridge near YBI – the new bridge will maintain five lanes in each direction but will feature wider lanes with full shoulders.

West of YBI, the suspension span (actually two suspension bridges connected at the anchorage structure) consists of five lanes on each deck, with lanes ranging from 11 feet-7 inches to 11 feet-11 inches wide. Access to and from Treasure Island/YBI occurs via a series of substandard ramps that pose significant challenges to drivers entering and existing the mainline traffic stream on the bridge. Figure 4 illustrates a section of the suspension span.

Approaching the Bay Bridge on the East Bay side, I-80 and I-580 converge at a complex junction known as the "distribution structure". The distribution structure consists of a number of freeway connector ramps that funnel traffic from I-80 and I-580 into the toll plaza area at the base of the bridge. I-880 headed to the Bay Bridge bypasses the distribution structure and converges with the other freeway approaches at the toll plaza. A bank of metering lights is located 1,000 feet west of the toll plaza complex. The connector ramps from each freeway into the toll plaza area include dedicated high-occupancy vehicle (HOV)/transit lanes that bypass the toll plaza and the metering lights. The HOV lanes serve as a queue jump for HOVs and buses around the congestion that develops at the toll plaza during a typical weekday morning commute.

Figure 5 shows a schematic drawing of the toll plaza (as of September 2009), the three interstate freeways that approach the Bay Bridge from Oakland, and the number of lanes provided to each of the three payment types served at the toll plaza: Cash, Electronic Toll Collection (ETC) or "FasTrak", and HOV. During the AM peak period, which is defined in this study as 5:00 AM to 10:00 AM, lane assignments by payment type are:

- Lanes 1 – 2: HOV (serves I-880 and I-580)
- Lanes 3 – 6: Cash (serves I-580)
- Lanes 7 – 11: FasTrak (serves I-80 and I-580)
- Lanes 12 – 17: Cash (serves I-80 and I-880)
- Lane 18: FasTrak (serves I-880 and Grand Ave)
- Lane 19 – 20: HOV (serves I-880, Grand Ave, and I-80 HOV)

Traffic congestion on most weekdays occurs throughout the entire morning commute period. Day-to-day variations caused by lane blocking incidents or minor demand fluctuations can greatly exacerbate the normal congestion experience. As a result, congestion through the toll plaza area and the distribution structure can also vary. Queues typically extend from the toll plaza back several thousand feet. However, there is sufficient storage so that queues do not extend back to the distribution structure during "normal" operating days. A normal operating day is one without an incident (e.g., traffic accident or lane closure).

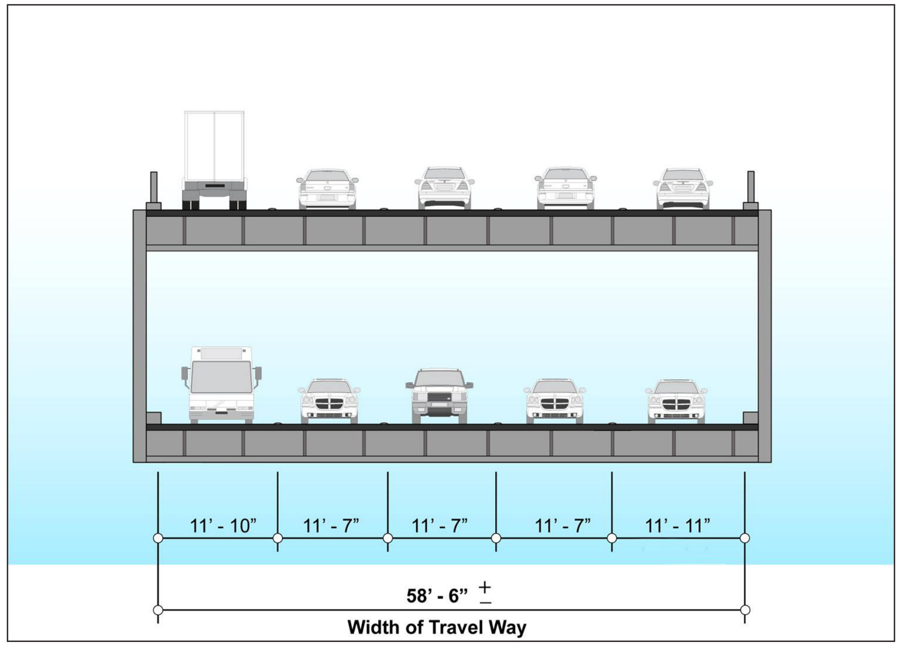


Figure 4: Bay Bridge Suspension Span Roadway Cross-Section

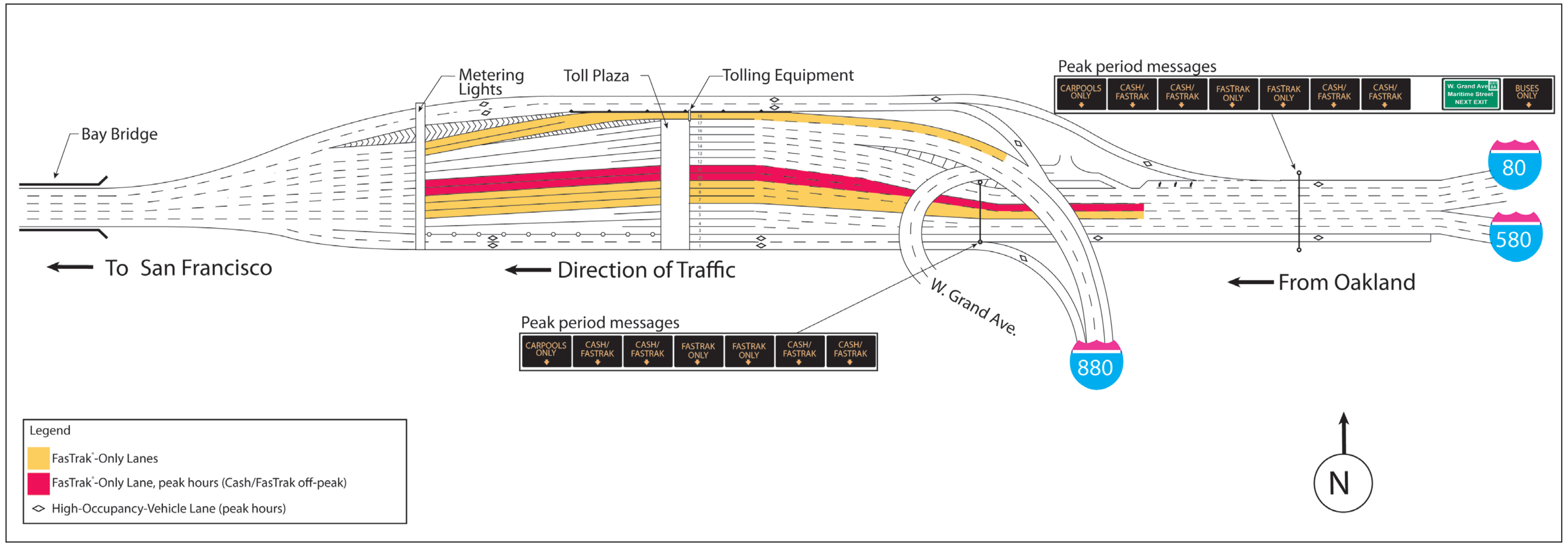


Figure 5: Toll Plaza Complex (source: MTC)

Bay Bridge Corridor Background

Caltrans policy is to accept queues at the toll plaza in lieu of excessive congestion on the bridge spans. To accomplish this goal, Caltrans monitors the flow of traffic at the western base of the Bay Bridge using loop detectors and activates the metering lights once the bridge's capacity is exceeded. This occurs at a flow rate of approximately 9,300 vehicles per hour. Once the metering lights are activated, Caltrans adjusts the rate to maintain this level of traffic flow onto the bridge. This effectively minimizes congestion and queuing on the structure. Once activated, the metering lights are the controlling factor for vehicle capacity in the corridor. The presence of queues upstream of the metering lights is a clear indication that traffic demand currently exceeds the capacity of the bridge.

Carpools and buses traveling in the HOV bypass lanes avoid most of the congestion associated with the toll plaza and the metering lights, while queues in the general purpose lanes extend upstream from the metering lights into the toll plaza complex and beyond. These queues can extend into the weaving portions of the distribution structure and impact traffic flow on the multiple freeways connecting into the Toll Plaza. For transit and HOVs, these queues already impact operations on the worst days. The West Grand connection for transit/HOVs is especially impacted.

In the AM peak hour, the Bridge Corridor serves more than 40,000 westbound person-trips by auto and transit modes. AC Transit carries about 3,000 westbound passengers on the Bridge in the morning peak hour, while BART carries about 14,000 westbound passengers in the AM peak hour. Table 3 provides a breakdown of existing AM travel demand from the East Bay to San Francisco:

Peak Hour Travel, AM/Westbound, Bay Bridge Corridor	
Vehicles:	9,300
Auto Passengers:	23,000
AC Transit Passengers:	3,000
BART Passengers:	14,000
TOTAL PASSENGERS	**40,000**

Source: Cambridge Systematics, 2007

Table 3: AM Peak Hour Travel - Westbound Bay Bridge

Every study conducted for MTC over the last 20 years has predicted that peak period demand in the Bay Bridge Transbay corridor would surpass the total transportation capacity of the corridor during some horizon year, which has generally been recognized as sometime between 2010 and 2020. While the current economic recession has likely moved that point out a few years, it is likely to occur within a generation. Every study gives buses a crucial role in bridging this capacity gap.

Figure 6: Toll Plaza

Microsimulation Model Development

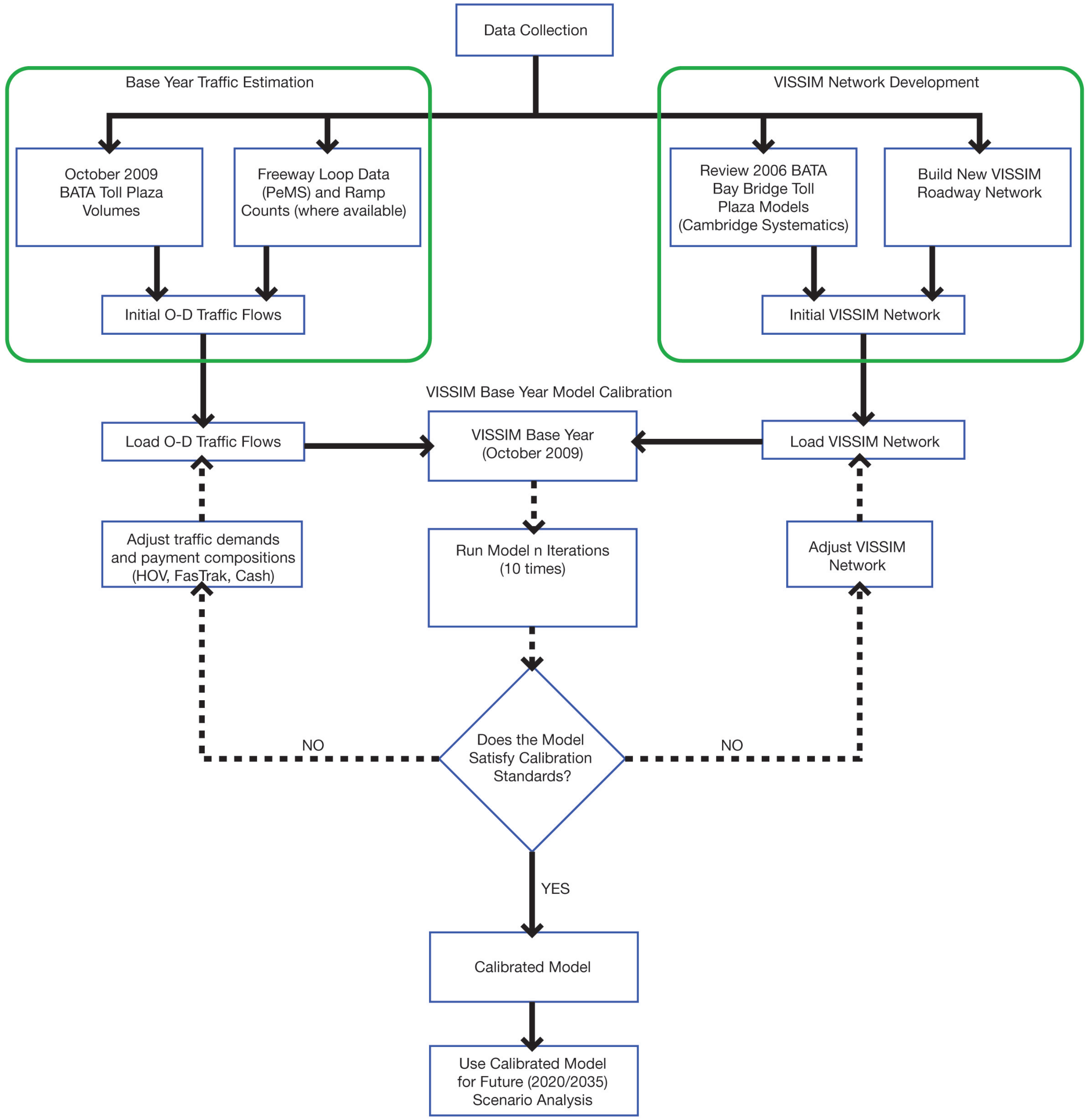


Figure 7: Bay Bridge AM Model VISSIM Development and Calibration

Methodology

To accurately model traffic conditions, Arup developed a microsimulation model of the westbound Bay Bridge corridor using the software program VISSIM[1]. VISSIM is a stochastic, multi-modal, microscopic simulation program that models the interaction of individual users (drivers, transit vehicles, pedestrians) in complex freeway and urban transportation systems. The modeling process includes developing a calibrated Base Year (2009) model that replicates current conditions. The calibrated model, along with future traffic projects, becomes the basis for developing a Future (2035) No Project model. The Future (2035) No Project scenario provides an estimate of how severe congestion along the corridor could become without any additional infrastructure improvements. This analysis serves as a basis for developing potential improvement options for the corridor. This section details the development of the Base Year (2009) calibrated model and the Future (2035) No Project model.

Model Scope

The study analyzes traffic and transit operating conditions during the AM peak period commute for the freeways carrying traffic across the Bay Bridge from the East Bay and Oakland into San Francisco.

The study area includes the following:

- Approximately 24 miles of mainline freeway and 15 freeway interchanges
- Three interstate freeway corridors in the East Bay with the following gateways:
    - Interstate 80 (I-80) westbound north of the I-80/I-580 merge in Albany
    - I-580 eastbound north of the I-80/I-580 merge in Albany
    - I-580 westbound east of the State Route 24 (SR 24)/I-980 junction in Oakland
    - I-880 northbound south of the Jackson Street on-ramp in Oakland
    - I-80 in San Francisco to a point south of the US-101/Central Freeway junction

Base Year (2009) VISSIM Model Development and Calibration

Figure 7 presents a flow chart that depicts the development and calibration of the Base Year (2009) VISSIM model. This section details this process.

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[1] PTV America

Microsimulation Model Development

Data Collection, Field Observations, and VISSIM Model Development

The Bay Bridge corridor model was based on an earlier VISSIM model of the toll plaza area developed by Cambridge Systematics in 2006 for the Bay Area Toll Authority (BATA). The operation of the toll plaza, the metering light algorithm, and core vehicle performance and driver behavior assumptions were incorporated from this earlier work. The Cambridge Systematics model focused primarily on the toll plaza and was calibrated to volume and travel time data collected specifically for the BATA study. Based on this earlier work and calibration, VISSIM is considered a valid tool to model toll plaza and freeway operations along this corridor.

For the Bay Bridge Corridor Congestion Study, the original Cambridge Systematics model was expanded to include a larger portion of I-80, I-580 and I-880 in the East Bay and a larger portion of the highway system through downtown San Francisco. The Bay Bridge AM peak period model contains the following features:

- The VISSIM model area includes about 24 miles of freeway mainline
- The model runs for a five-hour AM peak period (5:00 AM to 10:00 AM)
- The first hour (5:00 to 6:00 AM) is included as a "warm-up" period to congest the network; no simulation data or statistics are collected for this warm-up period
- The model analysis is conducted for the four-hour period from 6:00 to 10:00 AM
- Traffic volumes are loaded in 15-minute increments
- Only the inbound direction to San Francisco is modeled
- The most recent toll plaza configuration from September 2009 is included
- Three major toll payment types are included and summarized in the model calibration: Cash, Electronic Toll Collection (FasTrak), and High Occupancy Vehicle (HOV)
- The toll plaza metering light signal algorithm is included
- Existing Transbay bus routes were modeled using current schedule information

Field observations, a review of previous studies, and an initial data analysis indicate a number of factors that determine traffic flow and capacity through the toll plaza area. Key findings of existing practices include:

- The metering lights are activated between 6:15 and 6:30 AM when throughput measured at the five lanes at the base of the Bay Bridge exceeds a threshold of approximately 9,000 to 9,200 vehicles per hour.
- Once the metering lights are activated, a brief "all-red" phase is shown to allow a small queue to develop at the metering light stop bar.
- Once the metering lights are activated, the metering cycle length and green time for Cash and FasTrak vehicles is determined by a complex algorithm that considers and prioritizes the throughput of HOV vehicles measured at the toll plaza while keeping the total flow constant.
- The metering algorithm monitors HOV flows on a one-minute basis and allocates the green time to Cash and FasTrak lanes at the metering lights.
- When the metering lights are activated, queues quickly stack up and extend back through the toll plaza complex
- Upstream traffic demand at the approaches into the toll plaza increases steadily throughout the AM peak period until approximately 8:30 AM, when demand to the Bay Bridge begins to subside.

Base Year Traffic Demand

Traffic demand data for the base year model conditions was developed from a number of sources:

- Detailed toll plaza volumes (by lane and payment type, for one-hour and five-minute intervals) were obtained for a period from January 2006 to December 2009
- Freeway mainline traffic volumes (hourly and 5-minute intervals) were developed using loop detector data obtained from the Freeway Performance Measurement System (PeMS)
- Ramp volumes in the East Bay were developed from counts published in the I-80 Integrated Corridor Mobility Project (DKS, January 2010)
- Ramp volumes in San Francisco were developed from counts collected by Arup, Fehr & Peers, and AECOM for other projects
- Origin and destination data used to develop vehicle routings in VISSIM were obtained from base year model runs of regional travel demand models developed by MTC and the San Francisco County Transportation Authority (SFCTA)

These data were used to define the initial traffic volume inputs and distribution of vehicular demand throughout the model area. The traffic volume inputs at origins in the model were developed on a 15-minute basis to better control demands within the model. Development of the model required a complete set of internally consistent and balanced traffic flows throughout the entire corridor. The toll plaza data represented the most robust dataset and was the focus of the overall calibration effort. Where it was necessary, traffic volumes were interpolated and balanced using the best available traffic counts and travel demand model information.

Base Year (2009) Model Calibration

Calibration is an iterative process that involves adjusting model parameters to produce a result that closely replicates field measured traffic conditions. The calibration strategy includes:

- Identifying appropriate calibration data and targets
- Identifying the appropriate model parameters to adjust or calibrate
- Modifying the selected parameters until traffic flow and capacity satisfies the calibration targets

The calibration process involved collaboration between the consulting team and Caltrans, MTC, and AC Transit. In addition, Cambridge Systematics conducted an independent review of the base year model calibration and found no major issues with the model's structure or assumptions.

The Bay Bridge model calibration must:

- Replicate the distribution of vehicles by payment type (Cash, FasTrak, HOV) across the toll plaza lanes
- Replicate a typical hourly volume profile at the toll plaza
- Replicate the metering light algorithm, including when the metering lights are activated and the green time allotted to Cash and FasTrak vehicles at the metering light stop bar
- Replicate traffic flow and queuing at the major freeway approaches (I-80, I-580, I-880) from the distribution structure into the toll plaza area

It should be noted that congestion throughout the corridor is highly variable and results from a number of different factors, including: existing traffic demand exceeding the capacity of the toll plaza, a high number of lane blocking incidents (e.g., accidents, vehicle stalls, etc.), and roadway geometric issues (e.g., lane drops, short weaving sections, etc.). Because of this variability, the consultant team analyzed the toll plaza and PeMS datasets to identify a set of potential observation days during October 2009 that experienced normal operating conditions with no major incidents. October 2009 was selected because it was one month after the installation of the "S-curve" on the Bay Bridge. Eleven mid-week days (Tuesday, Wednesday, Thursday) were considered: these days occurred before the eyebar failure and subsequent closure of the Bay Bridge (afternoon of October 27 to the morning of November 2).

Figure 8 plots the hourly volumes (5:00 – 10:00 AM) at the toll plaza for the eleven analysis days in October 2009. The minimum and maximum volumes for each hour are noted. October 11 was eliminated because an incident upstream of the distribution structure constrained the vehicle demand reaching the toll plaza. Of the remaining ten days, eight experienced the highest observed toll plaza throughput between 6:00 and 7:00 AM, while two experienced the peak between 7:00 and 8:00 AM.

October 8 was selected as the basis for the VISSIM model calibration because the hourly traffic profile is within the observed ranges plotted on Figure 7. All of the upstream and downstream traffic inputs in the VISSIM model were based initially on these October 8 traffic volumes. Using this one day to validate the model rather than an average of several days is preferred because averaging would smooth or flatten out the hourly traffic profile, or "peaking" profile, that is typically observed over the five-hour AM peak. The hourly traffic profile is a critical determinant of traffic operations and queuing at the toll plaza and along the entire corridor. As Figure 7 illustrates, October 8 falls in the median of the "typical days" that were evaluated as the basis for calibration.

The breakdown of traffic by payment type at the toll plaza is also an important component of the calibration. Table 4 provides a summary of the traffic payment compositions for the calibration day.

% Total Volume	5:00-6:00	6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00
Vehicles/Hr	6,020	9,284	9,000	8,893	8,530
CASH %	31%	27%	20%	22%	28%
FT %	50%	45%	35%	38%	48%
HOV %	18%	28%	45%	41%	24%

Table 4: Traffic Payment Compositions

The core driver behavior and vehicle performance parameters developed for the previous Cambridge Systematics toll plaza model were left unchanged. In particular, Cambridge Systematics developed a more aggressive lane changing driver behavior for use around the toll plaza complex to help with the quick lane merges and lane drops. These lane changing behaviors were used on various links around the toll plaza to help with the model calibration.

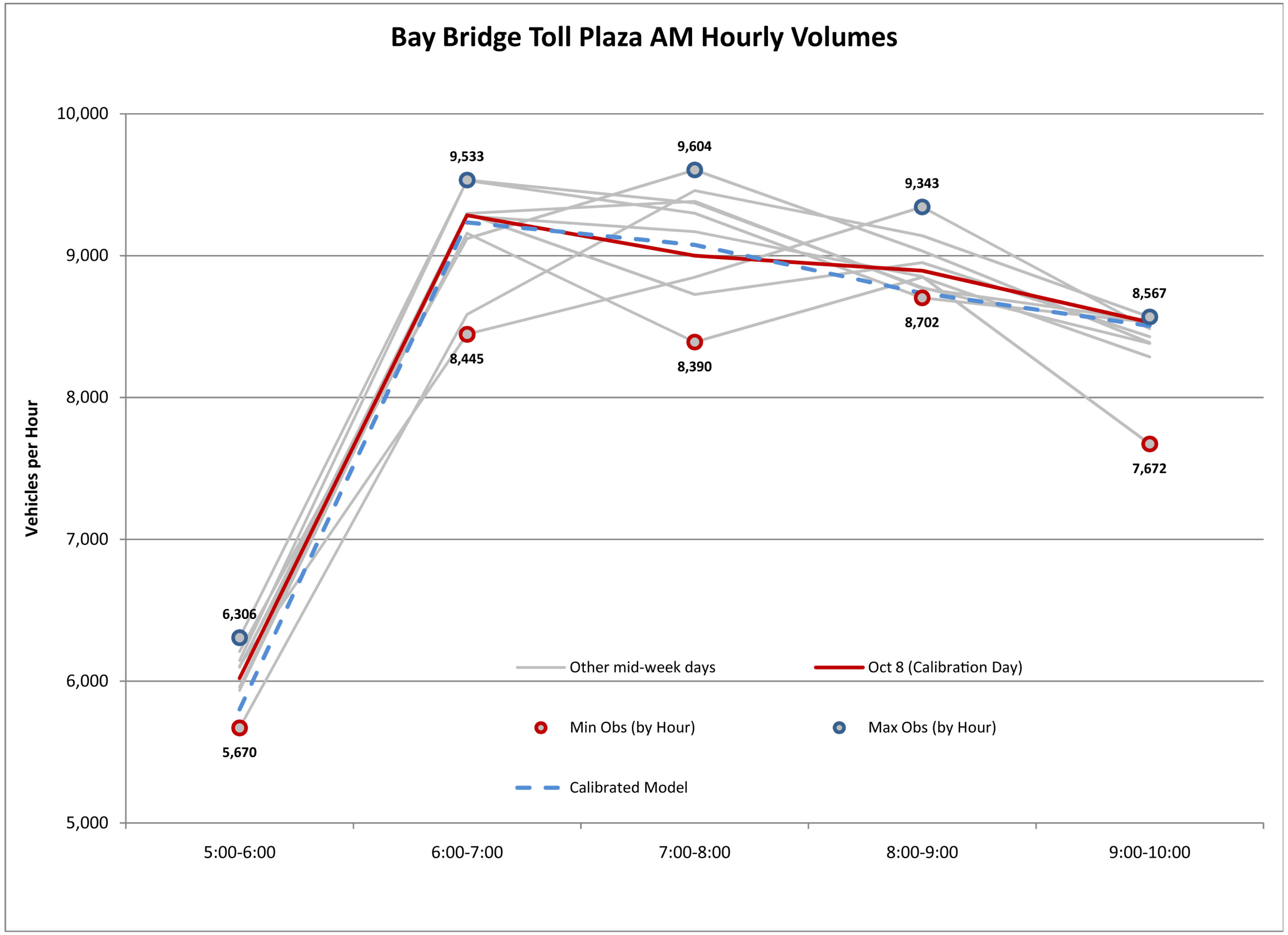


Figure 8: Bay Bridge Toll Plaza Calibration Volumes

Microsimulation Model Development

Calibration Criteria

Calibration typically involves comparing various measures of effectiveness (MOEs) between the model and observed values. Vehicle throughput, travel time and vehicle queues are commonly used MOEs. In addition, a visual audit of the simulation video provides a useful reality check.

The calibration presented in this study focuses on the traffic throughput at the toll plaza by hour and by payment type. Special attention was also paid to the shape of the hourly volume contour and the activation of the metering lights. Calibrated models should reflect these factors as it is primary influence on the accumulation of queuing and congestion upstream of the toll plaza. Upstream volumes at the approaches from the distribution structure to the toll plaza were monitored. The MOEs were compared between the base and future year models to assess the effectiveness of various improvements in the analysis.

The primary performance measure selected was the GEH statistic, which is a standard traffic modeling measure used to evaluate the accuracy of flows given wide ranges in observed volumes. The GEH formula is named for its inventor, Geoffrey E. Havers, a traffic engineer who developed the statistic in the 1970s. The GEH formula is:

$$GEH=\sqrt{\frac{2(M-C)^2}{M+C}}$$

Where
M = modeled volume
C = observed volume

Caltrans staff recommended using a target GEH statistic of less than 2.0 at the toll plaza (the lower the GEH the better the fit between modeled and observed volumes) because this is the primary bottleneck along the corridor. For an observed volume of 9,000 vehicles, a GEH of 2.0 represents a difference of only +/- 190 vehicles. In this example, a GEH of 2.0 translates into a 2 percent difference.

Arup calculated the GEH statistic for each hour across the four-hour analysis period. GEH was also calculated by payment type (Cash, FasTrak, HOV) to ensure vehicle processing is modeled accurately. This criterion exceeds guidelines established by the Federal Highway Administration (FHWA) and Caltrans, which typically call for a GEH below 5.0 for 85 percent of observed counts.

Calibration Actions

The toll plaza and upstream approaches were the focus of the calibration. The following issues were identified and addressed during the calibration:

- Vehicle speed and flow upon activation of the metering lights – Vehicles are metered at a lower rate upon activation of the metering lights in order to slow vehicles and expedite the creation of a queue.
- Vehicle lane choice at the toll plaza – Fixed vehicle routes were terminated upstream of the toll booths, allowing vehicles the freedom to make lane choices based on queue length.
- HOV merging behavior downstream of toll plaza – the large volume of HOVs caused long queues as they attempt to merge with mainline traffic. Lane merge priorities were set to minimize queuing and prevent it from spilling back to the toll booths.

In order to achieve modeling results in accordance with the calibration criteria, adjustments to the model inputs were made. The following inputs to the model were adjusted during calibration to achieve the validated model:

- Hourly origin destination data – Relative flows between origin and destination points
- 15-min demand profiles – Absolute traffic flows from an origin
- Hourly vehicle payment types – The percentage of vehicles using each payment type at the toll plaza
- Metering light algorithm – The start and end times of the metering lights as well as the metering rate in each hour

Calibration Results

The VISSIM model was run 10 times with different random seeds. Executing multiple runs with different seed numbers allows the model to capture random variations in driver behaviors and decision making.

Table 5 provides the calibration results. The modeled volumes and the GEH results are averaged across the ten runs and are summarized for each hour and payment type combination (e.g., 6:00 – 7:00 AM for HOV). The GEH results of each payment type at each hour are the primary focus as they provide a higher resolution of traffic flow – 75% of modeled flows have a GEH < 2.0 and 100% are under 5.0. A full summary of the toll plaza results for each of the ten simulation runs are included in Appendix A.

Volumes	Observed/ Model	6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00	4-HR Total
Total	Observed	9,284	9,000	8,893	8,530	35,707
	Modeled	9,234	9,075	8,735	8,504	35,548
HOV	Observed	2,585	4,012	3,609	2,085	12,291
	Modeled	2,593	4,015	3,558	2,185	12,350
Cash	Observed	2,533	1,824	1,917	2,358	8,632
	Modeled	2,645	1,808	1,996	2,374	8,823
FasTrak	Observed	4,166	3,164	3,367	4,087	14,784
	Modeled	3,996	3,253	3,182	3,945	14,375
GEH[1]	Payment Type	6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00	4-HR Total
	Total	0.52	0.79	1.68	0.28	0.84
	HOV	0.16	0.04	0.86	2.17	0.54
	Cash	2.20	0.37	1.79	0.32	2.04
	FasTrak	2.66	1.56	3.24	2.24	3.39

[1] GEH = Statistic used to compare modeled volumes to observed traffic counts. A target GEH < 2.0 is the goal, although a GEH < 5.0 is a typical modeling target

Table 5: Calibration Results

Microsimulation Model Development

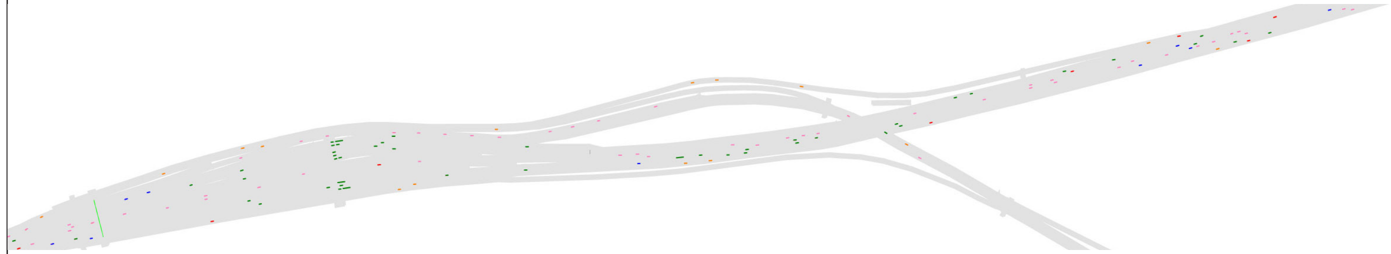
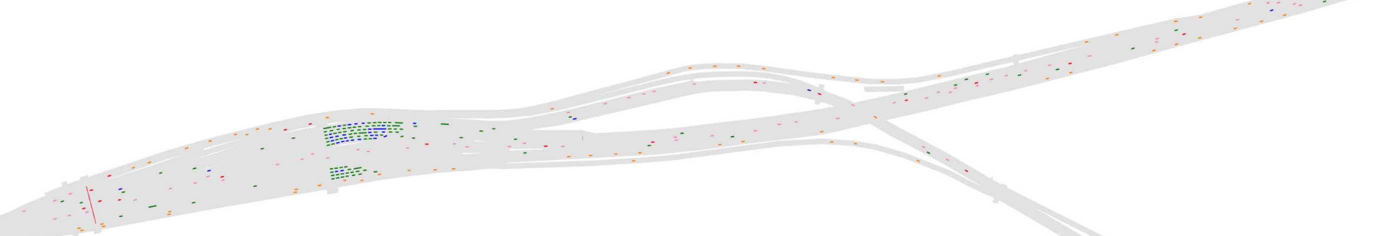
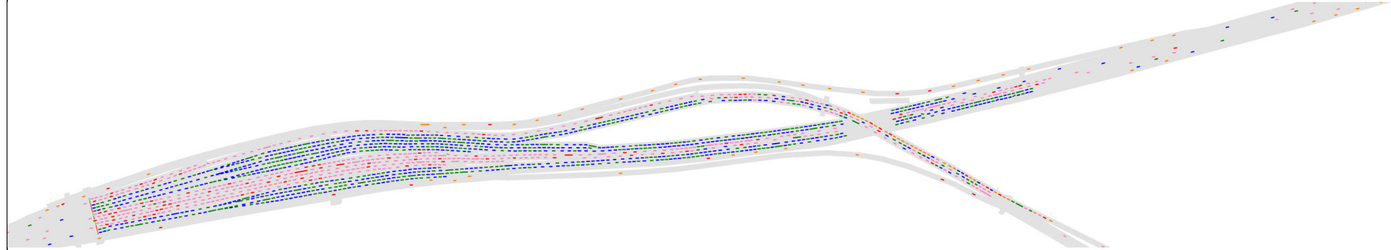
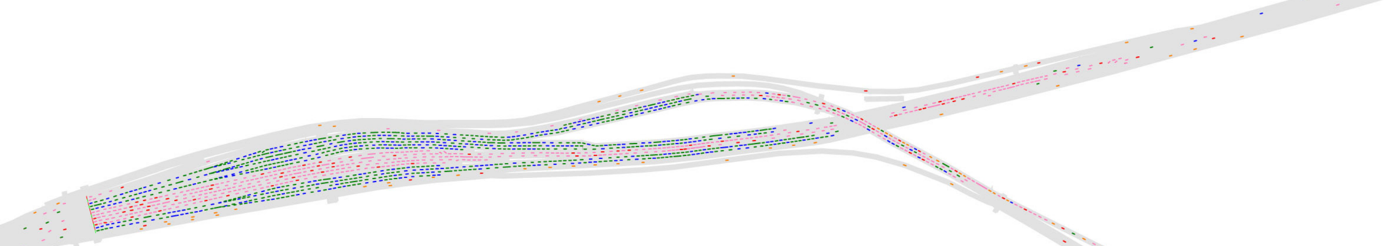
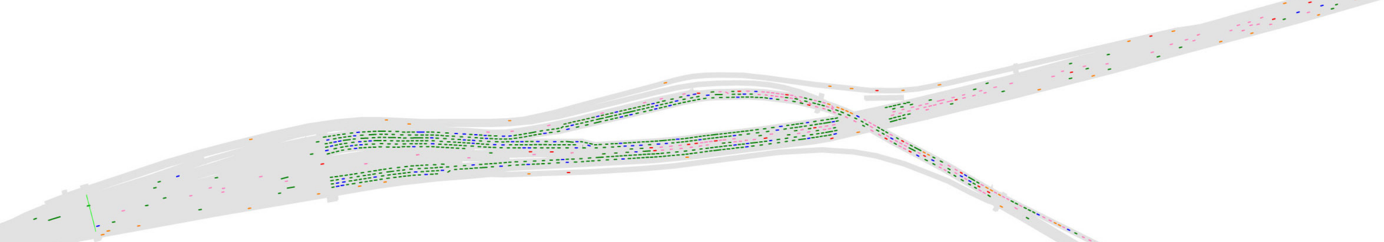
Hour	Base Year (2009) Vehicle Queuing at the Bay Bridge Toll Plaza by Hour(VISSIM Screenshots)
6:00AM	
7:00AM	
8:00AM:	
9:00AM:	
10:00AM	

Figure 9: Calibration Queuing by Hour

The results presented in Table 5 indicate the following:

- All of the GEH statistics (100 percent) are less than 5.0
- All of the Toll Plaza hourly **totals** have a GEH less than 2.0
- 70 percent of the hour/payment type combinations have a GEH less than 2.0
- 30 percent of the hour/payment type combinations have a GEH between 2.0 and 4.0

These low GEH statistics represent model volumes that are within 5 percent of the observed values. Small differences do exist, but these are caused by the activation and operation of the metering lights. As stated previously, the metering logic in the model differs slightly from the actual logic used in the field. The consistently low GEH statistics indicate that the model is reasonably replicating throughput at the toll plaza and the metering lights, which satisfies the basic calibration criteria.

A visual audit of the queuing upstream of the toll plaza further supports these calibration findings. Figure 8 provides a series of VISSIM screenshots that show the progression of queues at the toll plaza at 6:00, 7:00, 8:00, 9:00, and 10:00 AM.

Microsimulation Model Development

Future Year (2020/2035) No Project Model Development

Future (2020) and (2035) No Project scenarios were developed to predict future traffic and transit operations along the corridor without any additional infrastructure improvements. The Future No Project models analyze 2020 and 2035 future traffic projections with the same freeway network and toll plaza payment assumptions as the calibrated Base Year model described above. This section describes the traffic forecasting process used to develop the demands for the Future No Project VISSIM models.

Travel Demand Forecasts

This section describes the forecasting process used to develop the background traffic volumes for the microsimulation analysis of the future improvement scenarios. Future traffic forecasts were developed after a review of four Bay Area regional travel demand models:

- Metropolitan Transportation Commission (MTC)
- San Francisco County Transportation Authority (SFCTA)
- Alameda County Congestion Management Agency (ACCMA)
- Transbay Mode Choice/Caltrain Downtown Extension Studies

The purpose of considering the four models was to assess the range of future year traffic demand. While the four models are all based on the same ABAG demographic information, some differences inevitably arise. The project team focused on two of the model forecasts – the MTC and the SF-Champ. These models were identified as generating the "high" (MTC) and "low" (SFCTA) traffic estimates. (The MTC forecasts higher overall traffic volumes, although the SF-Champ model was slightly higher).

Table 6 shows demand model traffic volumes on the Bay Bridge for both the MTC and SF-Champ models. Year 2010 near-term forecasts are shown to represent existing conditions and Year 2035 volumes are the horizon year volumes. Both models show similar volumes on the Bay Bridge – both in the base and future years (the difference in AM peak period traffic volumes on the Bay Bridge between the two models is less than four percent).

Table 6 also illustrates where the East Bay generated traffic is headed to – either to Downtown San Francisco, to the Central Freeway/8th Street or further sound on US 101. The models show general agreement that a little more than half the traffic is headed downtown. However, the models do not agree where the rest of the traffic is going to – The SF-Champ model predict more traffic is headed to Northwest San Francisco (Central Freeway, 8th Street), while the MTC model shows more East Bay generated traffic is headed south on US-101. However, the question of where the East Bay generated traffic not headed to downtown goes to is not critical; the focus has been to examine East Bay to Downtown San Francisco travel patterns.

Both models show that traffic demand is forecast to increase by 16% on the Bay Bridge during the four hour AM peak period. Both models also agree on the percentage change in trips to downtown San Francisco (growth is about 20% for each model). In addition, trips generated by the new Treasure ISland development (as identified in the TIEIR) were also added to Westbound Bay Bridge traffic for future years.

Model Year	Bay Bridge	SF Downtown exits at Fremont, Harrison	To SF NW exits at 8th, Central Fwy	Through South of the Central Fwy
2010 MTC Model	36,400	19,600	5,800	11,000
2010 SF-Champ	37,700	19,000	9,600	9,100
2035 MTC Model	42,300	23,500	7,000	11,800
2035 SF-Champ	43,800	22,700	10,200	10,900
Percent of Traffic (Sums to 100%)				
2010 MTC Model		54%	16%	30%
2010 SF-Champ		50%	25%	24%
2035 MTC Model		56%	17%	28%
2035 SF-Champ		52%	23%	25%

Source: Cambridge Systematics

Table 6: Bay Bridge Corridor Traffic Forecasts

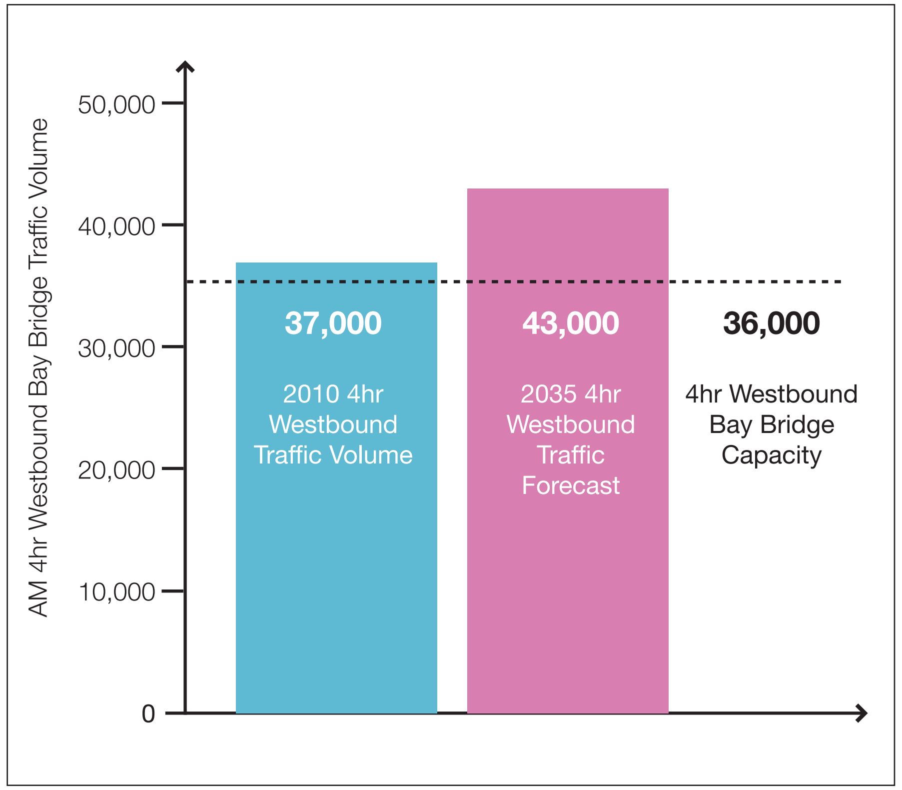


Figure 10: Existing and Future Bay Bridge AM Peak Period Demand

It is useful to note that the four hour volumes shown in the travel demand models are likely not achievable. Currently, the maximum one hour volumes on the Bay Bridge are limited to about 9,200 vehicles per hour. Thus, the Bay Bridge is currently at capacity for the entire four hour AM peak period today in 2010. Additional growth in traffic on the Bay Bridge can only be accommodated through a longer peak period than four hours, conversion of eastbound lanes to westbound and from additional mode shifts to BART, AC Transit and ferries. Figure 10 provides a comparison of the existing and future AM four-hour peak period demand at the Bay Bridge.

At the Toll Plaza, downtown-bound vehicles represent 50 to 55 percent of total Bay Bridge westbound traffic (this range holds for both the MTC and the SF-Champ model and in both current and future projections). In the future, while the percentage of trips beyond downtown stays about the same, the absolute numbers increase by about 2,000 trips in the peak period. These additional trips compare with additional downtown trips on a facility with no excess capacity. The key findings from the travel demand forecasts are:

- Demand increases by 10 to 16 percent by 2035
- The MTC and the SF-Champ models generated 2035 forecasts that varied by only 5 percent on the westbound Bay Bridge
- Future demand exceeds capacity, so the following is likely to occur: queuing and congestion will worsen, peak-hour spreading will occur, and commuters will shift to buses or BART (or all three occur)

The consultant team decided to use the SF-Champ model to generate the traffic forecasts used in the analysis of future scenarios. All of the forecast models were similar enough in their outputs, but the SF-Champ model produced forecast results that were appeared more reasonable and stable around critical freeway interchanges, particularly in San Francisco.

Table 7 compares the Base Year (2009) and Future (2035) traffic forecasts at the major origins on the VISSIM network. Future (2020) No Project traffic volumes were estimated using linear interpolation.

Gateway/On-Ram	Base Year (2009)	Future (2035)	% Growth
I-80 Start Point on 580	28,756	29,500	3%
I-580 Start Point on 80	11,458	12,500	9%
I-80 Buchanan St On	2,379	2,500	5%
I-80 Gilman St On	1,218	1,900	56%
I-80 University Ave	1,899	1,999	5%
I-80 Ashby On	1,634	2,140	31%
I-80 WB Powell On	3,016	4,100	36%
I-80 EB Powell On	640	900	41%
I-580 Start Point on 24	14,761	17,000	15%
WB SR 24 to 580 Connector	6,383	6,500	2%
EB SR 24 Connector to 580	5,176	5,600	8%
I-880 Start Point	18,596	22,400	20%
I-880 Jackson St On	2,436	2,900	19%
I-880 Union St On	3,222	3,270	1%
I-880 Maritime/Grand On	4,467	4,667	4%
East Bay Total	106,041	117,876	11%
I-80 TI On	1,300	3,200	146%
I-80 4th On	4,557	4,700	3%
I-80 7th On	829	1,400	69%

Source: Cambridge Systematics, Arup, 2009

Table 7: Base Year (2009) Volumes and Future (2035) Traffic Forecasts

Performance Measures

Performance measures and targets were established by the consultant team in consultation with the stakeholders in the study. The performance measures are grouped into three categories: congestion, transit travel, and transit reliability. A set of targets is defined for each measure. The performance measures and targets for the westbound Bay Bridge corridor analysis are:

- **Congestion**
  - The length of the Toll Plaza queue *should not* extend beyond the distribution structure
  - Total vehicle-hours of delay and person-hours of delay in each 2035 improvement scenario *should be less* than the 2020 and 2035 No Project condition
- **Transit Travel**
  - Transit speeds should average *not less* than 42 miles-per hour (mph) between the distribution structure and the TTC
  - Notes: The distance from the distribution structure to the TTC is approximately seven miles. A bus traveling at 42 mph will cover this distance in about 10 minutes.
- **Transit Reliability**
  - No individual peak period transit trip should exceed 14 minutes between the distribution structure and the TTC.

The Base Year and Future No Project model results are used to identify if the scenario satisfies the performance measure targets.

Microsimulation Model Development

Base Year (2009) and Future (2020/2035) No Project Results

This section compares travel speed, delay, and transit MOEs obtained from the VISSIM model for Base Year (2009) and Future (2020) and (2030) No Project scenarios. The evaluation of the performance measures is also provided.

Travel Speed Comparison

The Base Year (2009) and Future No Project VISSIM model results were compared. One interesting aspect of microsimulation modeling tools is the ability to collect various measures of congestion, such as average travel speed, on a link level. Travel speed serves as a good proxy for overall traffic operations and level of congestion. Figure 10 compares the estimated model travel speeds at the toll plaza (at 8:00 and 9:00 AM) for the Base Year (2009) and Future (2035) No Project scenarios. Figure 11 shows that in the future, travel speeds at the toll plaza will decline considerably by 8:00 AM.

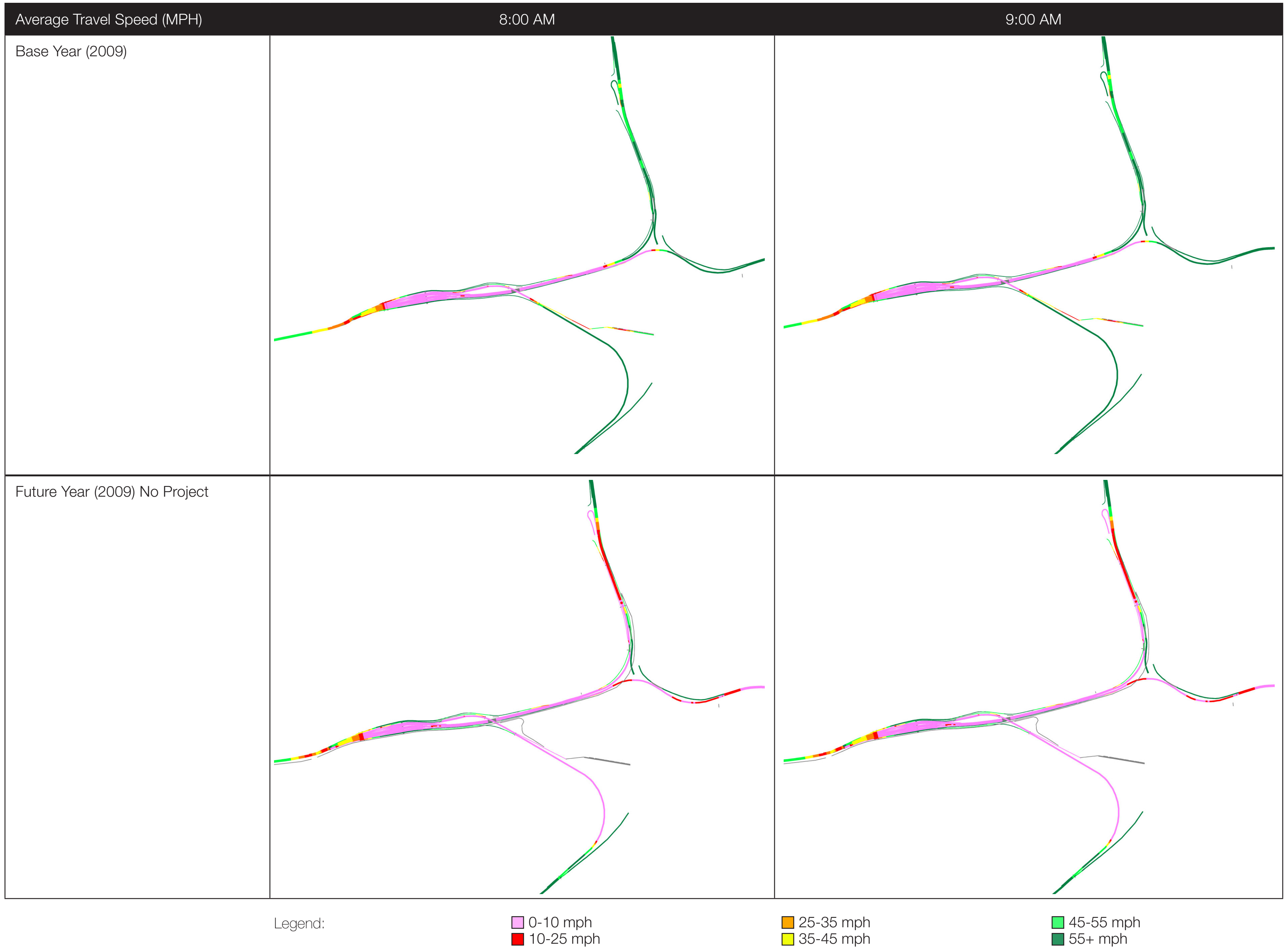


Figure 11: Average Travel Speeds at the Toll Plaza

Vehicle Delay, Person Delay, and Transit Analysis

Table 8 and Table 9 compare the vehicle-hours of delay and person-hours of delay results for Base Year and Future No Project conditions. These delay MOEs are collected systemwide and reflect the total delay experienced by each vehicle on the 24-mile network.

Vehicle-Hours of Delay	6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00	Total
Base Year (2009)	265	1,335	2,350	3,703	7,654
Future (2020) No Project	**391**	**1,620**	**2,725**	3,269	8,006
Future (2035) No Project	**524**	**2,058**	**3,208**	**3,707**	9,497

Table 8: Vehicle-Hours of Delay

Person-Hours of Delay	6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00	Total
Base Year (2009)	409	2,010	3,583	5,587	11,588
Future (2020) No Project	**607**	**2,490**	**3,937**	4,711	11,745
Future (2035) No Project	**802**	**3,375**	**4,720**	5,501	14,998

Table 9: Person-Hours of Delay

Table 10 and Table 11 compare the bus speed and travel time from each freeway approach at the distribution structure (I-80, I-580, or I-880) to the TTC bus ramp.

Bus Travel Speeds (MPH)	6:00-7:00	7:00-8:00	8:00-9:00
Base Year (2009)			
I-80 to the TTC	55.5	53.9	46.8
I-580 to the TTC	52.4	48.5	**29.6**
I-880 to the TTC	57.1	52.9	49.7
Future (2020) No Project			
I-80 to the TTC	54.3	51.0	45.9
I-580 to the TTC	51.5	**37.9**	**19.2**
I-880 to the TTC	54.6	52.4	50.2
Future (2035) No Project			
I-80 to the TTC	51.9	47.6	**36.5**
I-580 to the TTC	50.9	**37.5**	**12.7**
I-880 to the TTC	54.5	**29.5**	42.8

Table 10: Bus Travel Speed (MPH) from the Distribution Structure to the TTC Bus Ramp

Bus Travel Time (Min)	6:00-7:00	7:00-8:00	8:00-9:00
Base Year (2009)			
I-80 to the TTC	9.7	10.0	11.5
I-580 to the TTC	9.7	10.5	**17.2**
I-880 to the TTC	10.0	10.8	11.5
Future (2020) No Project			
I-80 to the TTC	9.9	10.6	45.9
I-580 to the TTC	9.9	**13.4**	**26.5**
I-880 to the TTC	10.4	10.9	11.4
Future (2035) No Project			
I-80 to the TTC	10.4	11.4	**14.8**
I-580 to the TTC	10.0	**13.6**	**40.9**
I-880 to the TTC	10.4	**19.3**	13.3

Table 11: Bus Travel Time (Min) from the Distribution Structure to the TTC Bus Ramp

Microsimulation Model Development

Performance Measures and Targets

The performance measures provide a way to quickly summarize and compare the scenario results to the operating targets identified by the stakeholder group. Table 12 compares the congestion, transit travel, and transit reliability performance measures for the Base Year, Future (2020) No Project, and Future (2030) No Project scenarios.

The results in Table 12 indicate the following:

- Operating performance along the westbound Bay Bridge corridor will remain within acceptable performance targets until at least 2020
- However, future traffic growth will cause operating performance along the corridor to exceed acceptable performance targets by 2035
- Congestion upstream of the toll plaza is expected to increase and persist for a much longer period by 2035
- The worsening of vehicle queuing in 2035 will block the HOV bypass lanes at the toll plaza, which will have a negative effect on transit speeds and reliability

These findings clearly show that measures are needed to improve transit mobility in the corridor.

Performance Measures (8-9AM) Summary

Category	Measure	2009 Base Year	2020 No Project Target Met?	2035 No Project Target Met?
Congestion	Toll Plaza queue - Not Beyond Dist Structure	Pass	Pass	Fail
	Total Vehicle Hrs of Delay	2,350	2,725	3,208
	Chg from 2009 Base Year (%)	N/A	16%	37%
	Chg from 2035 Base Case (%)	N/A	N/A	N/A
	Total Person Hrs of Delay	3,583	3,937	4,720
	Chg from 2009 Base Year (%)	N/A	10%	32%
	Chg from 2035 Base Case (%)	N/A	N/A	N/A
Transit Travel	Transit speeds should average not less than 42 mph (measured from I-80)	47 mph = Pass	46 mph = Pass	37 mph = Fail
Transit Reliability	No individual peak period transit trip should exceed 14 minutes (measured from I-80)	11.5 min = Pass	12 min = Pass	15 min = Fail

Table 12: Performance Measures

Introduction

The analysis considers two different approaches to improving operations along the westbound Bay Bridge corridor during the morning commute:

1. **Alternative Metering:** Increase the metering rate at the Bay Bridge metering lights.
2. **Physical Improvements:** A package of physical improvements that include a westbound contraflow lane on the Bay Bridge, access points necessary to enter the contraflow lane on the East Bay side and exit the contraflow lane on the San Francisco side of the bridge, and extension of the HOV network in the vicinity of the toll plaza.

Alternative Metering Option

The alternative metering option assumes an increase in the rate that vehicles are metered at the Bay Bridge metering lights. This would increase the throughput on to the Bay Bridge, which could reduce the queuing upstream the toll plaza. Shifting the queue from upstream of the toll plaza and on to the bridge would reduce the likelihood of vehicles blocking the HOV bypass lanes. However, increasing the flow of traffic onto the bridge is likely to lead to a degradation of traffic conditions on the bridge. This increase in traffic on the bridge structure could impede bus travel.

Physical Improvement Options

Policy Context

A traditional option for mitigating traffic increases is to build more capacity. In the last 38 years (since a 1972 public referenda that rejected the Southern Crossing), regional and local Bay Bridge corridor policy has been to increase the efficiency of the current transportation network and prioritize investment in transit. As a result, there has been no significant increase in highway capacity in the corridor since the Bay Bridge was converted to 10 lane operation in the early 1960s. However, the efficiency of the existing system has increased substantially – the Bridge’s vehicle occupancy is almost 2.5 people per vehicle in the peak period, and BART regularly carries about 15,000 passengers per hour between Oakland and San Francisco in the peak hour (or more than six lanes of traffic on a traditional freeway).

Over the last decade, managed lanes have become an accepted tool to increase capacity and manage congestion. The Federal Highway Administration defines a managed lane as having most of these elements:

- The managed lane concept is typically a“freeway-within-a-freeway” where a set of lanes within the freeway cross section is separated from the general-purpose lanes.
- The facility incorporates a high degree of operational flexibility so that over time operations can be actively managed to respond to growth and changing needs.
- The operation of and demand on the facility is managed using a combination of tools and techniques in order to continuously achieve an optimal condition, such as free-flow speeds.
- The principal management strategies can be categorized into three groups: pricing, vehicle eligibility, and access control.

Using this definition, the Bay Bridge has been effectively “managed” since 1970 when the metering light and HOV bypass elements were incorporated into the Bridge. These elements have allowed for the Bay Bridge to carry more people on its lanes than any highway in California (23,000 in carpools and 3,000 in buses in the peak hour), and makes the facility second only to the New Jersey-New York Lincoln Tunnel in “people-moving” highways.

The Bay Area has embarked on a conversion of its HOV lane system to a HOT (high occupancy – toll) system, also called the “express lane” system. This system allows single occupant vehicles to “buy” into the HOV lanes. The public benefit in this approach is primarily financial and timing. The HOT system can be built sooner since funding would be available sooner compared with the traditional HOV lane financing approach. In addition, the transportation (tax) funding that would normally be dedicated to the HOV system can be used for other projects, and excess HOT toll revenues can finance transit services in the impacted corridors.

Most proposed Bay Area HOT projects simply convert the existing HOV lanes to HOT lanes, although some construction is required for tolling equipment and enforcement activities. However, some HOT lanes will involve new construction. One of the criticisms of the HOT network is that it focuses investment on the fringes of the region and not in the core.

In developing potential physical improvements, policy continuity was a prime consideration. The major physical improvements evaluated in the study considered:

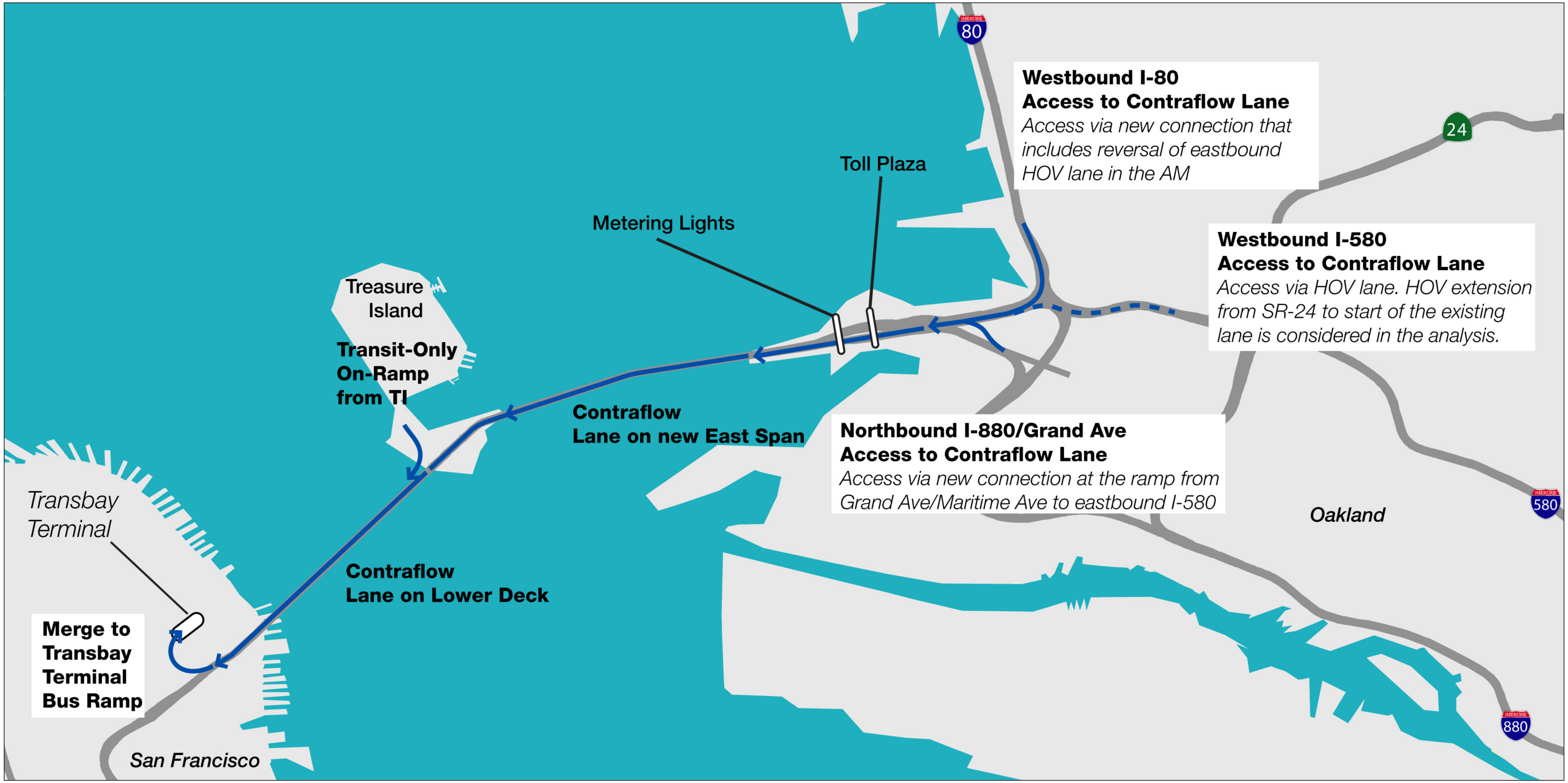
- Extensions of the HOV system to improve the ability of transit vehicles to bypass congestion both into the Toll Plaza and at the Toll Plaza.
- Contraflow transit lane on the lower deck of the Bay Bridge, operated as a HOT lane

The main policy nexus of the contraflow lane proposal would be to serve Transbay buses. Future year forecasts indicate that 200 to 300 bus trips per hour could use the Bay Bridge in the morning peak. Various reports provide guidance for a reasonable warrant to a dedicated bus lane. These reports provide a range from a 1976 Organization for Economic Co-operation and Development (OECD) report recommending a low end of 40 to 60 buses per hour (and passenger volumes of 1,600 to 2,400 passengers per hour) to the more recent American guidance contained in the National Cooperative Highway Research Program (NCHRP) Report 414 HOV Systems Manual recommending warrants of 200-400 buses per hour for an exclusive bus contraflow lane or 400-800 high occupancy vehicles (buses and carpools sharing the facility). In either definition, the literature suggests that an exclusive facility could be justified.

Caltrans’ HOV guidelines note that contraflow lanes can be considered when “the peak period directional traffic split is 35% or less during the design life of the project, and (2) if the speed of the opposing mixed-flow traffic is not reduced by implementation of the contraflow lane.” The current Bay Bridge west-east weekday peak period split is about 65/35 percent. While the Bay Bridge currently operates at capacity in the AM westbound direction, it operates at only about 70 percent capacity in the AM eastbound direction. The contraflow option considers using a reversible lane in the eastbound direction on the Bay Bridge. An example of a contraflow system is New York. The Port Authority of New York and New Jersey pioneered the concept with the Exclusive Bus Lane (XBL) in the Lincoln Tunnel (SR 495) which provides AM inbound access from New Jersey into Midtown Manhattan’s Port Authority Bus Terminal.

While the primary purpose of providing a contraflow lane is to maintain bus travel times and reliability, the contraflow lane would have spare capacity based on the projected bus trips. Future year projections assume approximately 300 Transbay buses per hour. This indicates that the contraflow lane could accommodate another 1,000 vehicles without impacting transit operations.

Improvement Options



Westbound I-80 Access to Contraflow Lane
Access via new connection that includes reversal of eastbound HOV lane in the AM

Westbound I-580 Access to Contraflow Lane
Access via HOV lane. HOV extension from SR-24 to start of the existing lane is considered in the analysis.

Northbound I-880/Grand Ave Access to Contraflow Lane
Access via new connection at the ramp from Grand Ave/Maritime Ave to eastbound I-580

Figure 12: Bay Bridge Corridor AM Physical Improvements

If consistent with the policy direction of major stakeholders, the lane could be operated as a HOT lane to allow private vehicles to use the lane. The Bay Bridge contraflow lane would then serve as a continuation of the Bay Area HOT network. Operating the contraflow lane as bus/HOT lane would allow single occupant vehicles to "jump the queue" for a premium fare up to the capacity of the lane and ensuring average speed was at least 42mph. HOVs would continue to use the existing upper deck HOV bypass. This would help finance the cost of constructing and operating the lane. The contraflow lane could also operate as a combined bus/truck facility, with trucks paying the toll to operate in the lane. While trucks comprise only 2 percent of total vehicle volume in the morning commute (approximately 200 trucks per hour), the size and poor acceleration performance of trucks on the incline of the Bay Bridge's eastern span can result in congestion.

Physical Improvement Options Considered

The physical improvement projects considered in the analysis focus on the construction of the contraflow lane on the Bay Bridge. The improvements also focus on providing access points to enter the contraflow lane from East Bay freeways and at YBI. Options for exiting the lane on the San Francisco side of the Bay Bridge are also discussed. Figure 12 summarizes the proposed physical improvements.

Contraflow Lane on the Bay Bridge

The Bay Bridge contraflow lane would comprise the number #1 lane in the eastbound direction across the entire length of the bridge. A movable "zipper" barrier would separate the contraflow lane from eastbound traffic. Figure 13 shows concept of the contraflow lane on the lower deck of the suspension span. The contraflow lane could be operated as a transit/HOT facility or as a bus/truck facility. Access into the contraflow lane from I-80, I-580, I-880, and Grand Avenue on the East Bay side would occur via new connector ramps. Access out of the contraflow lane on the San Francisco side of the bridge would occur with a new facility located at the First and Essex Street ramps. Details on these access points are described in the next section.

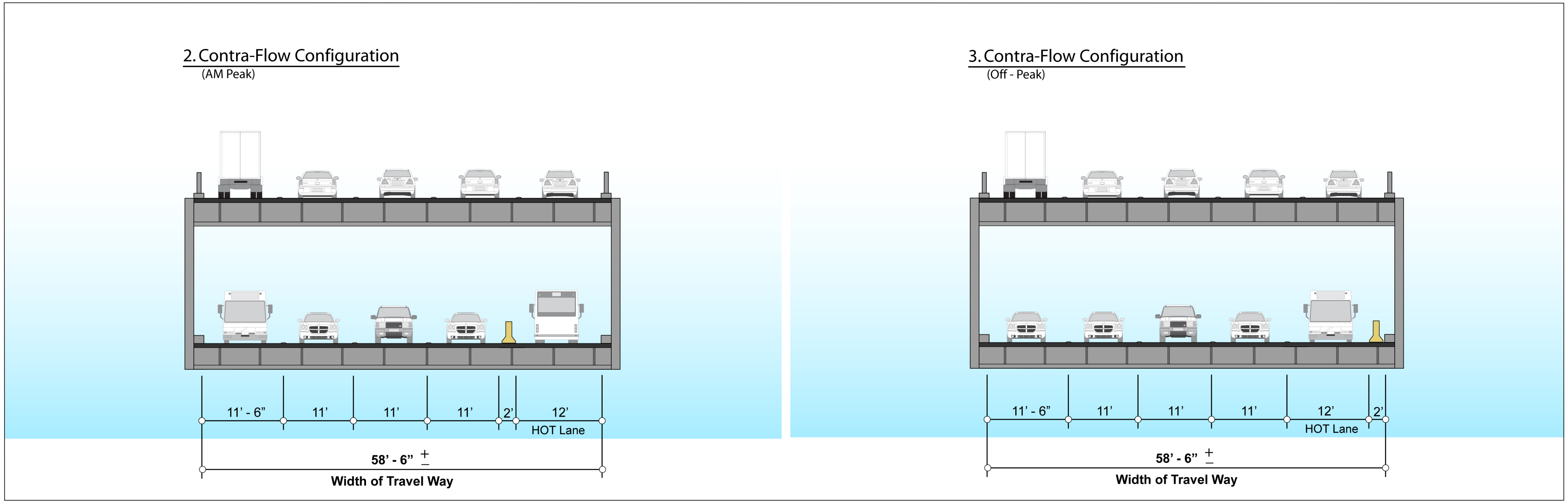


Figure 13: Contraflow Lane on Lower Deck

Improvement Options

Figure 14: I-80 Contraflow Access

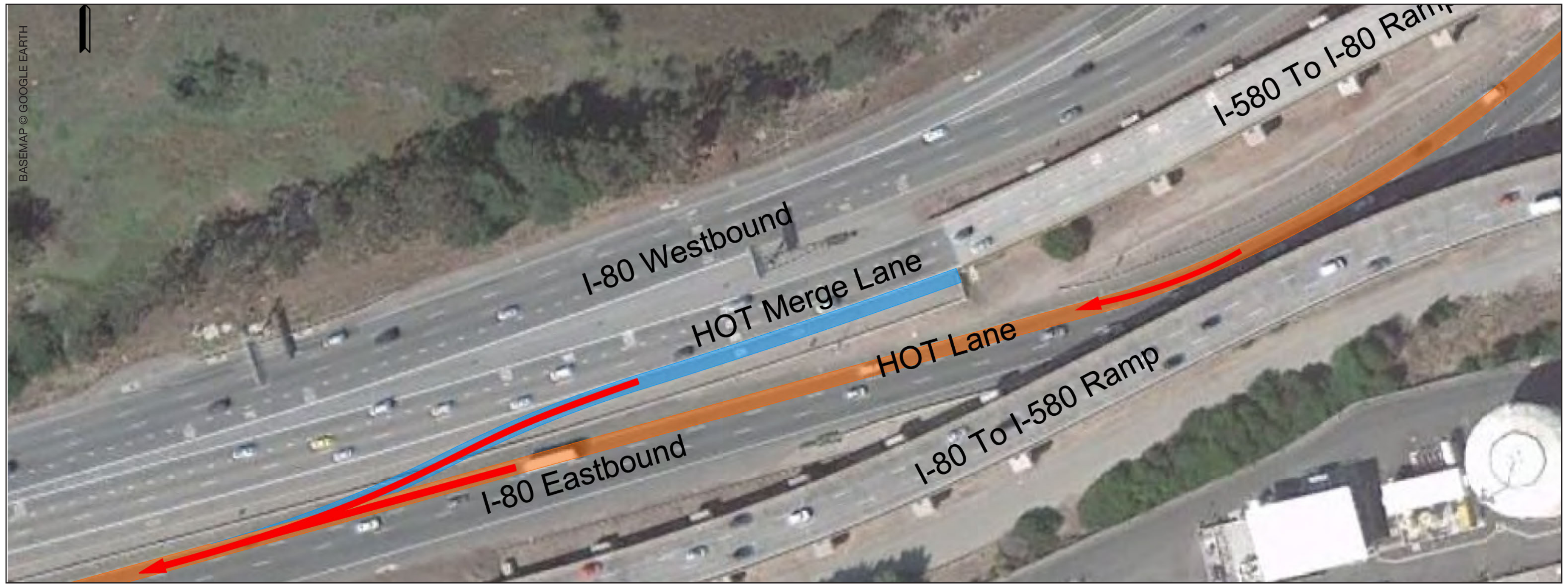


Figure 15: I-580 Contraflow Access

East Bay Options for Entering the Contraflow Lane

I-80 Access: The westbound HOV lane occupies the #1 lane along I-80 through the East Bay. As I-80 approaches the distribution structure, a flyover ramp connects the westbound HOV lane to the toll plaza. This flyover ramp begins its grade separation and divergence from I-80 approximately 1,500 feet south of Powell Street in Emeryville. In the opposite direction of travel, the eastbound I-80 HOV lane from the Bay Bridge merges with the northbound I-880 ramp at roughly the same location south of Powell Street.

It would be possible to begin the contraflow lane on I-80 between Powell Street and the beginning of the HOV flyover ramp. The contraflow lane would be created by reversing the eastbound I-80 HOV lane and providing a break in the median barrier to allow autos to crossover at this location. Westbound contraflow traffic (buses and HOT vehicles) would transition from the westbound HOV lane and into the reversible eastbound I-80 HOV lane. A moveable barrier would separate the contraflow lane from eastbound I-80 traffic in the mixed-flow travel lanes. The I-80 contraflow lane would the merge with the I-580 access point and connect to the contraflow lane on the bridge. Outside of the AM peak period the moveable barrier would be removed and traffic operations would revert to their present patterns.

Figure 14 shows the I-80 access point, the beginning of the contraflow section, and the crossover location south of Powell Street.

I-580 Access: The access from westbound I-580 into the contraflow lane could be provided at the base of the distribution structure. A break in the median barrier could be provided to allow vehicles to enter the contraflow lane. Figure 15 illustrates this concept.

The I-580 HOV lane would extend westbound from the I-580/SR-24 junction to the exisiting lanes west of the distribution structure. However, because this would be a particularly high-cost facility, the analysis analyzes scenarios both with and without this extension.

I-880 Access: I-880 traffic headed towards the bridge could access the contraflow lane using the existing HOV ramp. The HOV lane that leads to the south side of the toll plaza could diverge prior to the toll plaza and merge with the contraflow lane. The existing at grade roadway that crosses below the I-880 ramp and serves the Caltrans toll plaza from westbound I-80 would be closed to prevent conflicts.

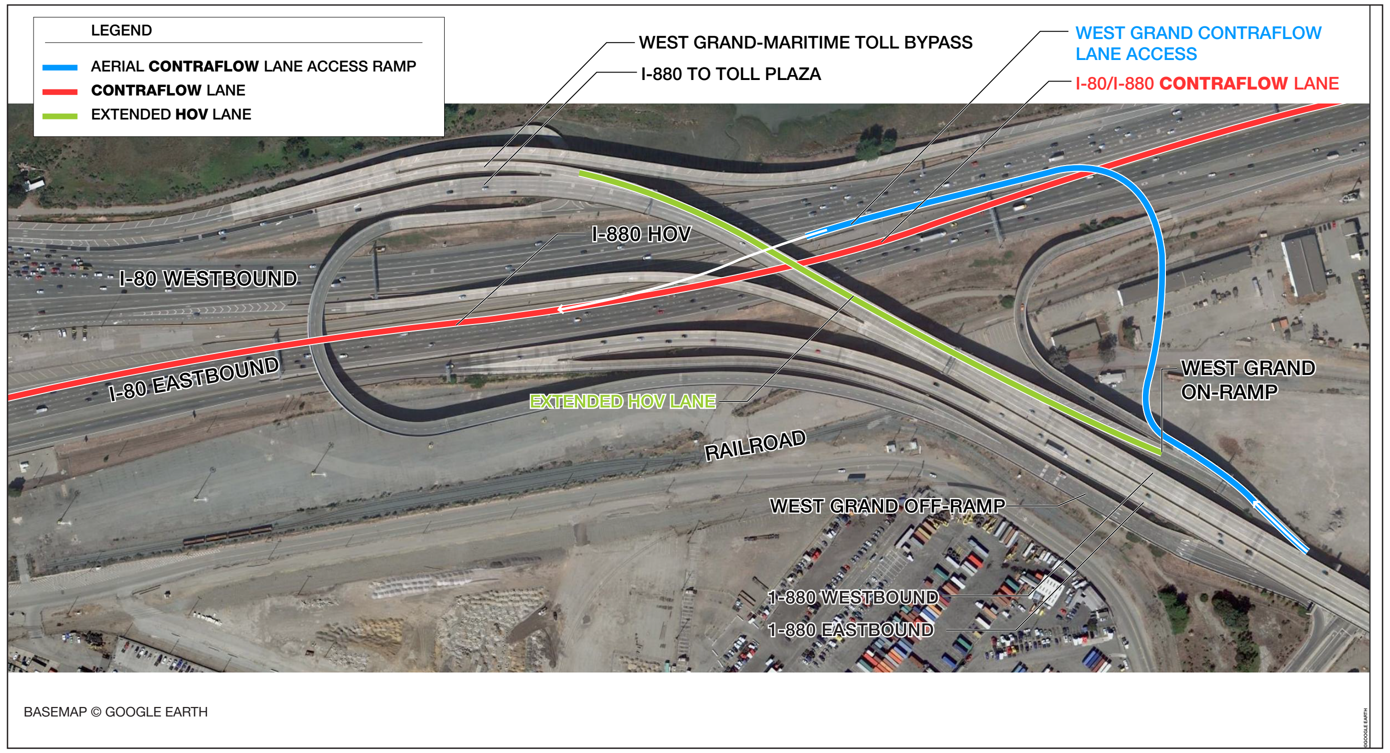


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Figure 16: West Grand Access - Option A

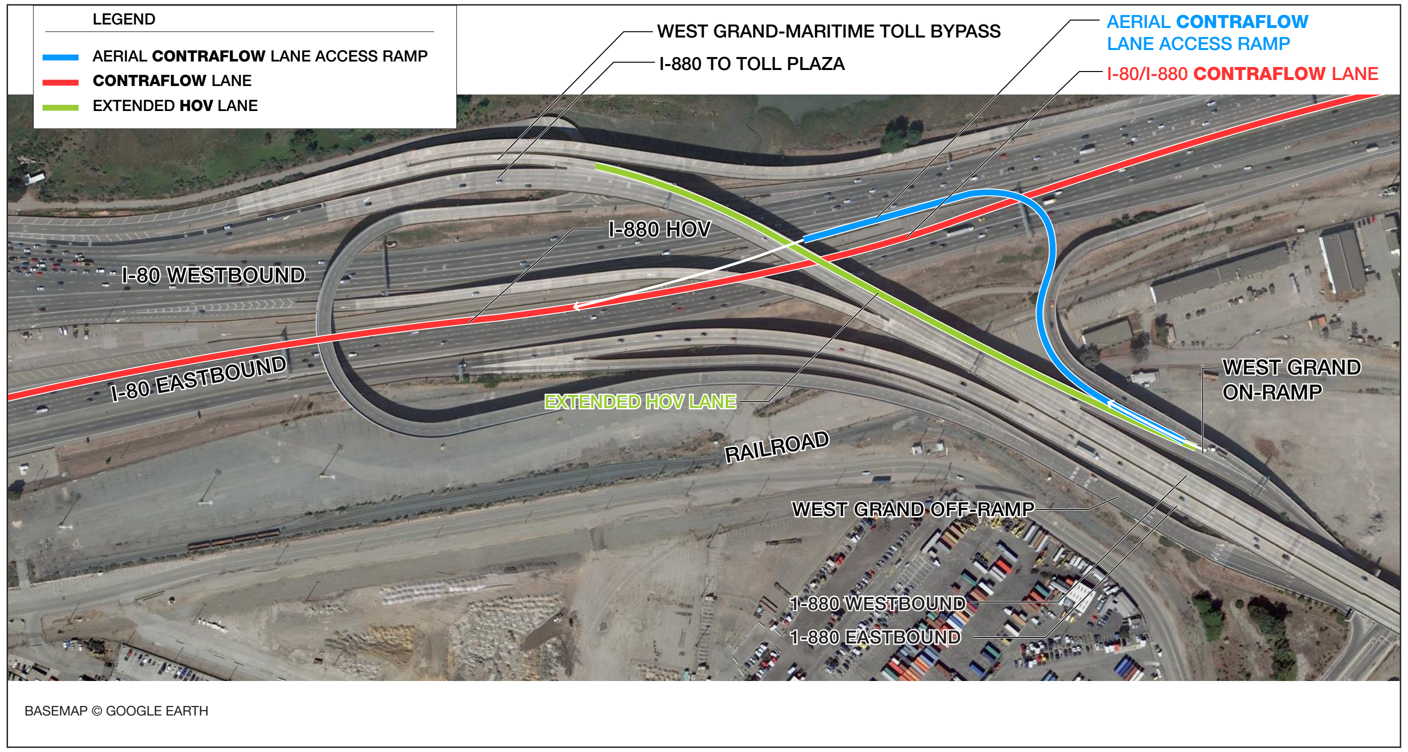

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Figure 17: West Grand Access - Option B

West Grand On-ramp Access: Providing a point of access to the contraflow lane from the West Grand Avenue and Maritime Street is complex but critical for AC Transit bus operations. The need for a straightforward and effective entrance is enhanced by proposals for a bus rapid transit (BRT) corridor along West Grand through Oakland. Four potential options have been explored. For all options it is assumed that the westbound West Grand-Maritime ramp above the I-80 eastbound and westbound roadways will be widened. This will extend the toll plaza bypass HOV lane to Maritime and allows for continuation of a bus/HOV lane along the West Grand structure located under the I-880 freeway.

West Grand Option A includes an aerial ramp beginning at the West Grand/Maritime Street intersection. As shown in Figure 16 the West Grand On-ramp could be widened for a dedicated contraflow lane access ramp. The contraflow lane access ramp would diverge to pass over Engineer Road, the railroad, I-580 eastbound on-ramp, and the eastbound I-80. The ramp would descend at approximately 5 percent touching down in the I-80 median. The contraflow access lane would utilize the existing toll plaza access lane where a zipper barrier would provide a merge into the facility.

West Grand Option B would diverge from the extended HOV lane on the widened westbound ramp. As shown in Figure 17 it would parallel the West Grand Avenue to I-580 eastbound connector, passing over the port railroad and I-80 eastbound roadway. The ramp would descend at approximately 8 percent and return to grade in the I-80 median, utilizing the existing toll plaza access lane as per Option A, where a zipper barrier would allow for a merge into the contraflow lane.

Improvement Options

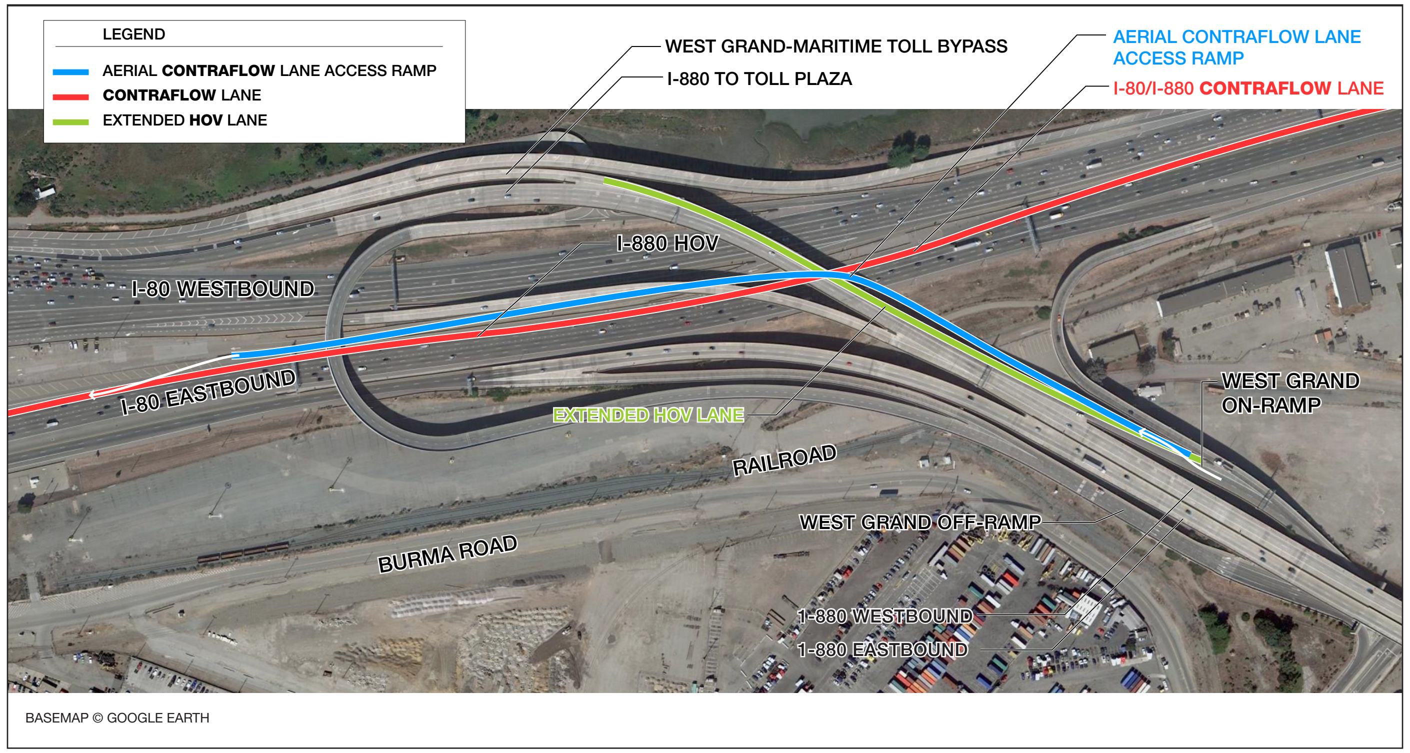

Figure 18: West Grand Access - Option C

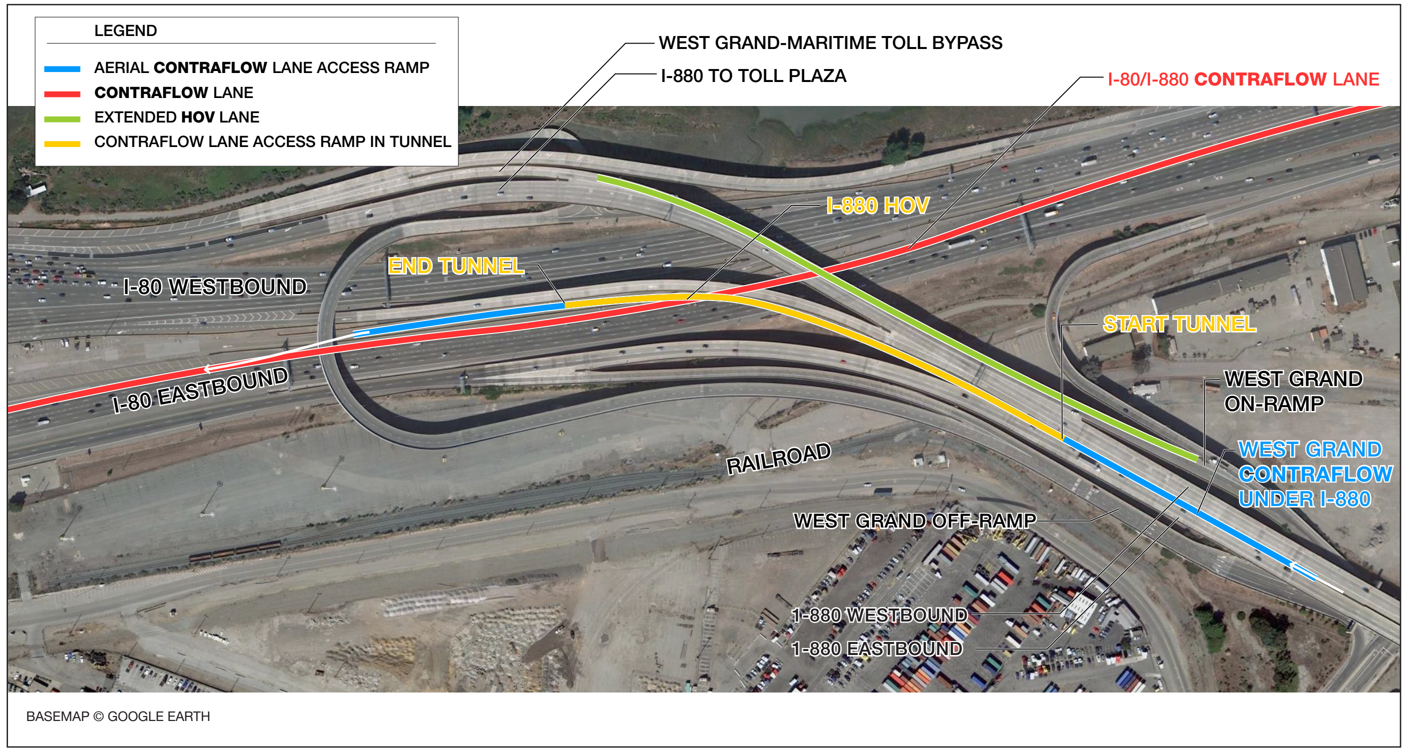

Figure 19: West Grand Access - Option D

West Grand Option C would diverge from the extended HOV lane on the widened I-880 westbound ramp. As shown in Figure 18 it would climb at approximately 8 percent to pass over I-880 westbound, I-880 HOV ramp, and I-80 to Maritime Avenue 'loop-back'. The ramp would descend at roughly 8 percent until touchdown within the current Caltrans plaza. A zipper barrier, as per Option A, would provide a merge into the contraflow lane.

West Grand Option D would tunnel beneath the eastbound traffic of I-80 and I-580 as shown as in Figure 19. From the Maritime St and West Grand Ave intersection the contraflow lane access ramp would be constructed at grade, beneath the I-880 elevated roadway. It would depress to pass under the railroad and eastbound I-80. The tunnel would return to grade at the east end of the Caltrans plaza and a zipper barrier would provide a merge into the HOT lane.

San Francisco Options for Exiting the Contraflow Lane

Approaching San Francisco the contraflow lane would be on the lower deck of the Bay Bridge. Westbound buses utilizing the lane are destined for the proposed Transbay Transit Center (TTC) and therefore must access it via the proposed TTC bus ramps, while private autos must be able to exit without entering the TTC facility. Two options were developed for exiting the contraflow lane. Alternatives were considered for routing buses via city streets but these were rejected due to congestion uncertainty and poor travel times reliability.

Exit Option A closes the Essex Street ramp and autos would exit on a reversible First Street ramp to Harrison Street. Buses would exit on a new lane ramp to the TTC bus ramps. The new contraflow lane ramp would use the closed Essex ramp at grade, pass beneath the exiting Fremont Street off-ramp, avoid existing columns, and tie into the TTC bus ramps in the vicinity of the Caltrans electrical substation. As a result, the Sterling Street ramp would be the sole downtown entrance for eastbound traffic in the AM peak period. Outside the AM peak period the First Street, Essex Street and Sterling Street ramps could remain for eastbound access to the Bay Bridge and the new bus connector lane to TTC would be closed. Moveable barriers could be used to close Essex Street in the AM peak and close the HOT lane bus ramp at other times. This option could be combined with SoMa Analysis Option A, the possible closure of Essex Street ramp.

Exit Option B maintains an eastbound on-ramp from Essex Street. Essex Street would be grade-separated with Harrison Street and lowered to pass beneath Harrison Street and a new bus ramp connection from the contraflow lane. Autos would exit on a reversible First Street ramp, with buses diverging from the contraflow lane onto the bus ramp connector. Essex Street and Sterling Street ramps could provide downtown entrances for eastbound traffic. The bus ramp would be grade separated above the lowered Essex Street, pass beneath the Fremont Street Off-ramp, and tie into the TTC bus ramps. The bus ramp connector horizontal geometry is dictated by column locations and vertical clearances above Essex Street and beneath Fremont Street Off-ramp. Essex Street would require an approximate gradient of 10 percent to rise from beneath the bus ramp connector to tie in with the existing First Street ramp nose. The horizontal curves and vertical clearances could be optimized with a more detailed study. Figure 20 illustrates this plan.

In Exit Option B, Essex Street ramps remain open and Essex Street would be widened to five lanes between Folsom and Harrison streets to increase eastbound queuing capacity. As suboptions, changes could be made to Sterling Street and First Street and these concepts can be coordinated with the SoMa PM improvement options that consider reconfiguring the downtown on-ramp.

Figure 20: San Francisco Contraflow Lane Exit Option B

Source: Yerba Buena Island Internal Road Network and Connection with Treasure Island Final Report, AECOM, 2009
Note: 1. Eastbound off-ramp reopened in Fall 2009.

Treasure Island and Yerba Buena Island Redevelopment Plan TIS

Figure 21: Treasure Island and Yerba Buena Island Ramps (Source: Fehr & Peers, AECOM, 2009)

Yerba Buena Island and Treasure Island

As part of the Bay Bridge East Span replacement project and the Treasure Island and Yerba Buena Island Redevelopment Plan, new on/off-ramps will be constructed on the east side of Yerba Buena Island (see Figure 21). These ramps will comprise standard right hand merging and diverging and will not affect the operation of the proposed contraflow lane. The existing eastbound off-ramp (number 5 in Figure 19) could be utilized as a bus only on-ramp to the contraflow lane in the AM peak period, subject to further operational considerations. As a further option, HOT vehicles from Treasure Island could be allowed to use the Contraflow lane using the bus ramps.

Improvement Options

Caltrans Toll Plaza Access

Regardless of the option pursued for West Grand contraflow lane access ramp, access must be provided to the Caltrans administration building. Under current conditions an entrance to the plaza is provided from #1 lane of both eastbound and westbound I-80. An additional access is provided from I-80 westbound #1 lane approximately 2,500 ft east of the toll plaza, which passes beneath the I-880 connection ramp farther east of the toll plaza. This roadway would be permanently closed in all options.

The contraflow lane access ramp from West Grand Ave, for all options, would serve as an entrance to the toll plaza at all times. Access from westbound I-80, I-580, and I-880 would be via the entrance immediately east of the toll booths, with additional access from the contraflow lane available in the AM peak.

Access from eastbound I-80 would be severed during the AM peak by the contraflow lane, however vehicles would be able to exit at West Grand Ave and loop back on the contraflow lane access ramp. Outside the AM peak, the current eastbound I-80 access would remain. In the AM peak period maintaining an eastbound move for vehicles exiting the toll plaza is an issue and requires further study.

Cost of Improvements

Arup analyzed the cost of delivering the range of improvement identified in this report. All estimates are considered “high-level” and it is recommended that an additional 25 percent general contingency be added for any budgeting purposes. The low costs represent the most modest improvements at the lowest unit costs, which the higher costs represent the most complex improvements at higher unit costs. Table 13 presents the cost estimates. The total improvement costs presented at the bottom of the table represent two potential packages; these are shown for illustrative purposes.

Improvement Option	Low Range Cost	High Range Cost
Core Items (Contraflow Lane, access from I-80/580/880, HOV extensions)	$40,300,000	$73,400,000
East Bay Options		
West Grand Option A	$12,300,000	$19,700,000
West Grand Option B	$8,200,000	$19,700,000
West Grand Option C	$17,500,000	$28,000,000
West Grand Option D	$31,700,000	$60,300,000
San Francisco Options		
Exit Option A	$2,500,000	$4,100,000
Exit Option B	$24,100,000	$42,900,000

Total Improvemant Costs		
Improvement Package Options	Low Range Cost	High Range Cost
Package 1: Core Items + West Grand Option B + Exit Option A	$51,000,000	$97,200,000
Package 2: Core Items + West Grand Option D + Exit Option Bt	$96,100,000	$176,600,000

Source: Arup, 2010

Table 13: Conceptual Cost Estimates

Further analysis is necessary to provide a more accurate budget for these improvements to provide a more robust analysis of the value of the improvements and to further define their costs.

Future Scenario Analysis

Figure 22: West Span

Analysis Scenarios

A series of analysis scenarios was developed to assess future operating conditions along the corridor. These scenarios were developed using the calibrated VISSIM model, the improvements listed above, and future 2035 traffic forecasts obtained from the San Francisco County Transportation Authority's (SF-Champ) travel demand model. Existing bus service within the corridor was obtained from current schedules, while future bus service assumptions were developed from TTC planning studies. Table 13 summarizes the analysis scenarios included in the analysis:

Scenario	Assumptions
Base Year (Calibrated Model)	• October 2009 traffic volumes and existing bus frequencies (approximately 100 peak hour bus trips) • October 2009 roadway network
Future 2020 No Project	• 2020 traffic volumes interpolated from 2035 SFCTA travel demand model and 2035 bus frequencies (approximately 300 peak hour bus trips) • No changes or improvements to the roadway network
Future 2035 No Project	• 2035 traffic volumes and bus frequencies • No changes or improvements to the roadway network
Future 2035 With Alternative Metering	• 2035 traffic volumes and bus frequencies • Increased metering rate, no changes to the network
Future 2035 With Physical Improvements	• 2035 traffic volumes and bus frequencies • Full set of physical improvements, no metering change • Assumes contraflow lane operates as a HOT lane with 1,000 vehicles per hour
Future 2035 With Reduced Set of Physical Improvements	• 2035 traffic volumes and bus frequencies • No I-580 HOV lane, no metering change • Assumes contraflow lane operates as a HOT lane with 1,000 vehicles per hour

Table 14: Analysis Scenarios

In the Future scenarios with the contraflow lane, an assumption was made that 1,000 vehicles per hour would use the lane as a HOT lane. This also reduces the traffic demand at the toll plaza by 1,000 vehicles. In the VISSIM model, 1,000 vehicles per hour were shifted out of the projected traffic flow and into the contraflow lane. This produces delay results in the two Physical Improvements scenarios that are better than the Base Year condition.

In reality, any available capacity in the freeway system resulting from vehicles shifting to a bus/HOT contraflow lane would get absorbed quickly. Any capacity increases associated with a bus/HOT contraflow lane could induce travelers to shift from transit to driving, or induce drivers to shift their trip back into the peak period. This phenomenon of "induced demand" is likely to occur in this context. The Bay Bridge corridor and the entire Bay Area region have high levels of "latent" demand that cannot be satisfied by the region's transportation system during peak periods. Induced demand was not considered in this study, as it requires a more detailed analysis of travel behavior and demand.

Regardless of how induced demand is considered, the transit analysis results are unlikely to change. The VISSIM analysis indicates that the physical improvements provide real benefits to bus operations. Additional congestion as a result of induced demand is unlikely to interfere with the ability of Transbay buses to access and operate within the contraflow lane.

Future Scenario Analysis

Future Scenario Microsimulation Analysis

VISSIM microsimulation models were developed for each analysis scenario using the assumptions detailed earlier in this report. This section provides a summary of the performance measures and targets and detail on the delay and transit measures.

Summary of Performance Measures and Targets

The performance measures and targets were evaluated for each scenario based on the results of the microsimulation modeling. Table 15 provides a summary of these results for the 8-9 AM hour. Table 2 indicates whether the target is satisfied – "Pass" – or exceeds the target – "Fail".

The results in Table 2 indicate that the westbound AM corridor would experience acceptable operating conditions through 2020. However, the analysis predicts that conditions for both transit and autos would degrade to unacceptable levels by 2035. The two Physical Improvement scenarios could substantially improve mobility through the corridor, particularly for transit. The results indicate that the physical improvements examined in this study have clear operating benefits. The consultant team also evaluated an option to increase metering rates onto the Bay Bridge. This scenario provided the worst service of all options studied.

The microsimulation data supporting the results in Table 15 are provided in the following sections. These sections describe vehicle delay, person delay, and transit speed and travel times.

Performance Measures (8-9AM) Summary

Category	Measure	2009 Base Year	2020 No Project Target Met?	2035 No Project Target Met?	2035 Alternative Metering Target Met?	2035 With Physical Improvements Target Met?	2035 With Reduced Set of Physical Improvements Target Met?
Congestion	Toll Plaza queue - Not Beyond Dist Structure	Pass	Pass	Fail	Pass	Pass	Pass
	Total Vehicle Hrs of Delay	2,350	2,725	3,208	3,680	2,168	2,288
	Chg from 2009 Base Year (%)	N/A	16%	37%	57%	-8%	-3%
	Chg from 2035 Base Case (%)	N/A	N/A	N/A	15%	-32%	-29%
	Total Person Hrs of Delay	3,583	3,937	4,720	6,256	3,254	3,426
	Chg from 2009 Base Year (%)	N/A	10%	32%	75%	-9%	-4%
	Chg from 2035 Base Case (%)	N/A	N/A	N/A	33%	-31%	-27%
Transit Travel	Transit speeds should average not less than 42 mph (measured from I-80)	47 mph = Pass	46 mph = Pass	37 mph = Fail	27 mph = Fail	53 mph = Pass	53 mph = Pass
Transit Reliability	No individual peak period transit trip should exceed 14 minutes (measured from I-80)	11.5 min = Pass	12 min = Pass	15 min = Fail	20 min = Fail	10 min = Pass	10 min = Pass

Table 15: Performance Measures

Vehicle Delay

Vehicle-hours of delay were analyzed for the four-hour modeling period for each of the five scenarios. Vehicle delay was measured for vehicles in the network crossing the Bay Bridge; this measurement excludes vehicle trips to other destinations within the network, as well the delay associated with continuing on through San Francisco. Table 15 presents the vehicle-hours of delay results by scenario. Values highlighted are delays that exceed the delay targets. The Future (2035) With Physical Improvements scenario is the only one that meets the performance criteria for each hour.

Vehicle-Hours	6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00	Total
Base Year (2009)	265	1,335	2,350	3,703	7,654
Future (2020) No Project	391	1,620	2,725	3,269	8,006
Future (2035) No Project	524	2,058	3,208	3,707	9,497
Future (2035) With Alternative Metering	585	2,899	3,680	3,352	10,516
Future (2035) With Physical Improvements	225	989	2,168	3,295	6,677
Future (2035) With Reduced Set of Physical Improvements	240	1,086	2,288	3,349	6,962
2035 No Project vs Base Year	98%	54%	37%	0%	24%
2035 With Physical Improvements vs Base Year	-15%	-26%	-8%	-11%	-13%
2035 With Physical Improvementst vs 2035 No Project	-57%	-52%	-32%	-11%	-30%

Table 16: Vehicle-Hours of Delay Results

Person Delay

Person-hours of delay were based on vehicle-hours of delay and assumptions of vehicle occupancy. Bus occupancy was collected from Transbay ridership counts estimated by hour. Table 16 reports the person-hours of delay results by scenario. The results are similar to vehicle-hours of delay, with the With Physical Improvements scenario satisfying the performance criteria.

Person-Hours	6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00	Total
Base Year (2009)	409	2,010	3,583	5,587	11,588
Future (2020) No Project	607	2,490	3,937	4,711	11,745
Future (2035) No Project	802	3,375	4,720	5,501	14,398
Future (2035) With Alternative Metering	858	4,608	6,256	5,173	16,894
Future (2035) With Physical Improvements	333	1,434	3,254	4,946	9,967
Future (2035) With Reduced Set of Physical Improvements	376	1,618	3,426	5,187	10,607
2035 No Project vs Base Year	96%	68%	32%	-2%	24%
2035 With Physical Improvements vs Base Year	-19%	-29%	-9%	-11%	-14%
2035 With Physical Improvementst vs 2035 No Project	-58%	-58%	-31%	-10%	-31%

Table 17: Person-Hours of Delay Results

Future Scenario Analysis

Transit Travel Speed and Travel Time

Average bus travel speeds were measured by each approach to the toll plaza for the four-hour analysis period. The results show that even in the Future (2035) No Project models, not all buses meet the 42 mph average speed. In the later hours congestion can reduce speeds on the approaches. The With Physical Improvements scenario maintains high speeds throughout the modeling period, outperforming even the Base Year model. Table 17 provides a summary of the transit travel speed results for the 6:00 to 9:00 AM period.

Travel times are measured between the distribution structure and the bus off-ramp to the Transbay Terminal. The highlighted values exceed the 10 minute travel time specified in the performance criteria. The With Physical Improvements model travel times remain under 10 minutes for I-580 and I-880; I-80 travel times exceed 10 minutes by around 12 seconds. Travel times are most consistent in the With Improvements scenario throughout the entire four-hour period compared to most other scenarios where travel times begin to vary during the later hours. Table 18 presents the travel time results by scenario.

Bus Travel Speeds (MPH)	6:00-7:00	7:00-8:00	8:00-9:00
Base Year (2009)			
I-80 to the TTC	55.5	53.9	46.8
I-580 to the TTC	52.4	48.5	29.6
I-880 to the TTC	57.1	52.9	49.7
Future (2020) No Project			
I-80 to the TTC	54.3	51.0	45.9
I-580 to the TTC	51.5	37.9	19.2
I-880 to the TTC	54.6	52.4	50.2
Future (2035) No Project			
I-80 to the TTC	51.9	47.6	36.5
I-580 to the TTC	50.9	37.5	12.7
I-880 to the TTC	54.5	29.5	42.8
Future (2035) With Alternative Metering			
I-80 to the TTC	53.7	51.1	27.1
I-580 to the TTC	51.0	35.5	21.6
I-880 to the TTC	54.5	29.4	32.9
Future (2035) With Physical Improvements			
I-80 to the TTC	53.0	52.4	52.8
I-580 to the TTC	54.8	53.6	52.9
I-880 to the TTC	59.0	58.4	58.0
Future (2035) With Reduced Set of Physical Improvements			
I-80 to the TTC	53.0	52.4	52.8
I-580 to the TTC	55.2	50.3	37.4
I-880 to the TTC	59.0	58.4	58.0
2035 No Project vs Base Year			
I-80 to the TTC	-6%	-12%	-22%
I-580 to the TTC	-3%	-23%	-57%
I-880 to the TTC	-4%	-44%	-14%
2035 With Physical Improvements vs Base			
I-80 to the TTC	-4%	-3%	13%
I-580 to the TTC	5%	10%	78%
I-880 to the TTC	3%	10%	16%
2035 With Reduced Set of Physical Improvements vs No Project			
I-80 to the TTC	2%	10%	45%
I-580 to the TTC	8%	43%	318%
I-880 to the TTC	8%	98%	35%

Table 18: Transit Travel Speed Results

Bus Travel Speeds (Time)	6:00-7:00	7:00-8:00	8:00-9:00
Base Year (2009)			
I-80 to the TTC	9.7	10.0	11.5
I-580 to the TTC	9.7	10.5	17.2
I-880 to the TTC	10.0	10.8	11.5
Future (2020) No Project			
I-80 to the TTC	9.9	10.6	11.8
I-580 to the TTC	9.9	13.4	26.5
I-880 to the TTC	10.4	10.9	11.4
Future (2035) No Project			
I-80 to the TTC	10.4	11.4	14.8
I-580 to the TTC	10.0	13.6	40.3
I-880 to the TTC	10.4	19.3	13.3
Future (2035) With Alternative Metering			
I-80 to the TTC	10.1	10.6	19.9
I-580 to the TTC	10.0	14.4	23.6
I-880 to the TTC	10.5	19.4	17.3
Future (2035) With Physical Improvements			
I-80 to the TTC	10.2	10.3	10.2
I-580 to the TTC	9.3	9.5	9.6
I-880 to the TTC	9.7	9.8	9.8
Future (2035) With Reduced Set of Physical Improvements			
I-80 to the TTC	10.2	10.3	10.2
I-580 to the TTC	9.2	10.1	13.6
I-880 to the TTC	9.7	9.8	9.8
2035 No Project vs Base Year			
I-80 to the TTC	7%	13%	28%
I-580 to the TTC	3%	29%	134%
I-880 to the TTC	5%	80%	16%
2035 With Physical Improvements vs Base			
I-80 to the TTC	5%	3%	-11%
I-580 to the TTC	-4%	-9%	-44%
I-880 to the TTC	-3%	-9%	-14%
2035 With Reduced Set of Physical Improvements vs No Project			
I-80 to the TTC	-2%	-9%	-31%
I-580 to the TTC	-7%	-30%	-76%
I-880 to the TTC	-7%	-49%	-26%

Table 19: Transit Travel Time Results

Figure 23: Morning Queue at Toll Plaza

Major Findings

San Francisco employment is projected to increase by about 50 percent over the next 25 years. Already 40,000 workers commute into the city from the East Bay in the peak hour; simply projecting a 50 percent increase beyond the current use will create demand beyond the peak hour capacity of the Bay Bridge and BART.

The major conclusions of the AM westbound analysis for the Bay Bridge Corridor Congestion Study are:

- The Bay Bridge and the toll plaza are currently congested on most days; however, vehicle queues do not typically extend back from the toll plaza to the distribution structure.
- The HOV bypass lanes are not typically blocked, which allows for acceptable bus operations.
- With projected increases in traffic along the corridor, queuing will worsen and routinely block the HOV bypass lanes in the future (traffic growth is projected at less than half-percent annually).
- Transbay buses will not meet transit performance targets by 2035, which will limit the performance of the Transbay Transit Center.
- The physical improvements show considerable promise for maintaining bus travel times and schedule reliability along the corridor, while also providing potential increases in person-trip capacity

SoMa Analysis

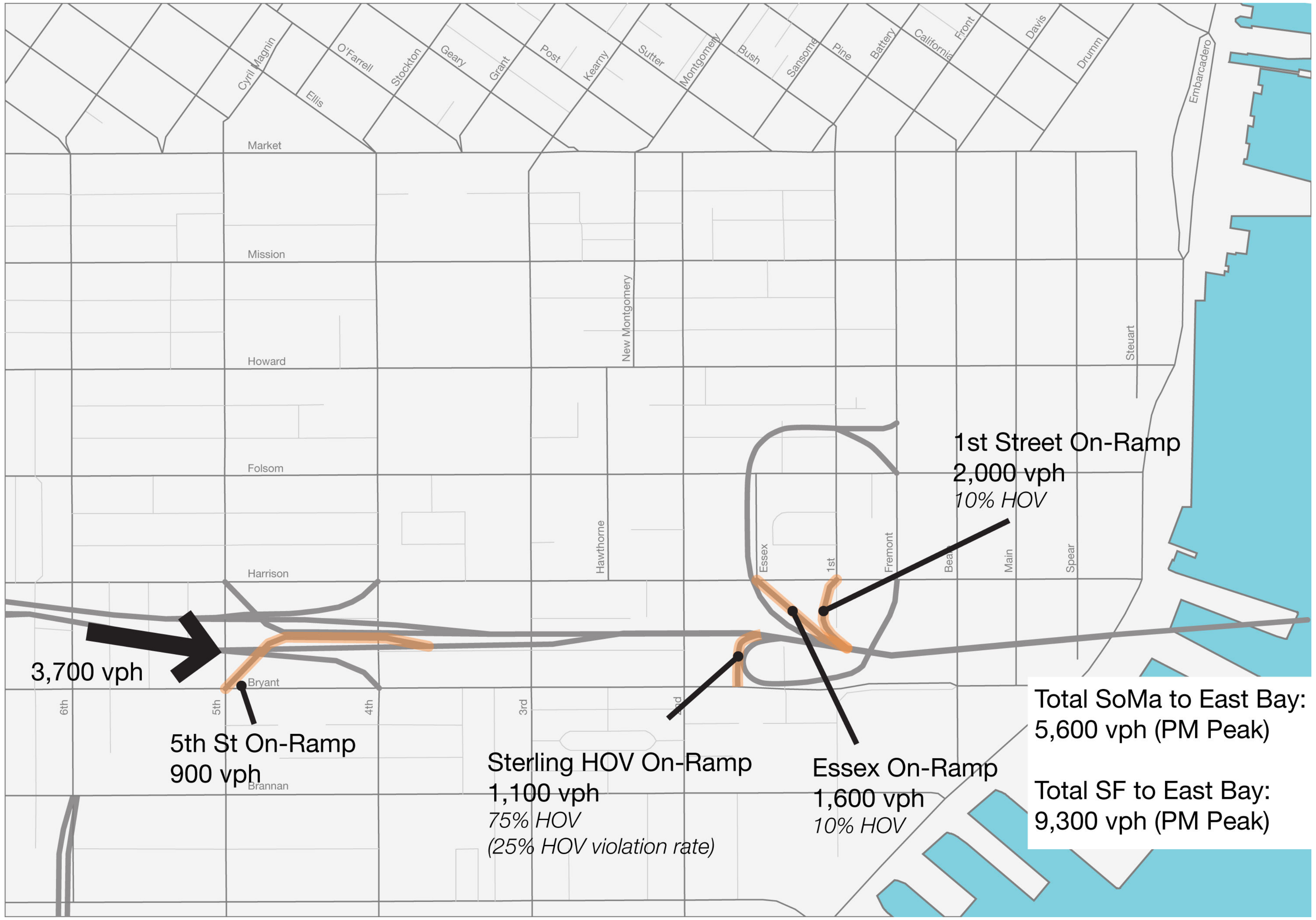

Figure 24: SoMa PM Peak Hour Ramp Volumes

Background

The "South-of-Market" (SoMa) area plays an important role in San Francisco and the Bay Area's transportation system. SoMa provides the critical roadway linkages between downtown San Francisco and the Bay Bridge. During the afternoon commute, automobile traffic leaving downtown San Francisco utilizes the SoMa roadway network to access the ramps serving I-80 and the Bay Bridge. This traffic queues on local streets as it is funneled towards the major Bay Bridge on-ramps at First Street, Essex Street, and the HOV on-ramp at Sterling Street (via Bryant Street). SoMa afternoon traffic, especially east of Fifth Street, is characterized by heavy congestion and frequently experiences gridlock on many streets.

Afternoon traffic conditions on SoMa streets vary considerably from day-to-day. While the causes of congestion within SoMa are very complex, operating conditions on the Bay Bridge and local fluctuations in demand exert considerable influence on local street operations. On a normal "functioning" day, the four SoMa on-ramps to the Bay Bridge at First, Essex, Sterling (HOV), and Fifth Streets serve approximately 5,600 vehicles during the PM peak hour. The PM peak hour volumes for each ramp are shown on Figure 24.

On days when the Bay Bridge is congested or there is an event in downtown (e.g., a San Francisco Giants baseball game), it is not unusual for vehicle queues to extend along First Street from the First Street on-ramp to Market Street, and along Harrison Street from the on-ramp to the Embarcadero. It is likely that even on a normal functioning day, the traffic demand is very close to the street system's capacity. It is conceivable that a relatively small increase in vehicle demand, perhaps in the range of 10 to 15 percent, could create conditions that result in a failing day. Figure 25 provides an example of queuing on a functioning "good" day compared to a failing "bad" day.

While system failure is difficult to measure precisely, field observations suggest that the local SoMa street network breaks down two to three days per week. System failure is typically defined as queues extending back from the Bay Bridge on-ramps on First Street to a point beyond Mission or Market Streets. When queues of this severity develop, intersections often get blocked, which can interfere with transit operations on Market, Mission, and Folsom Streets.

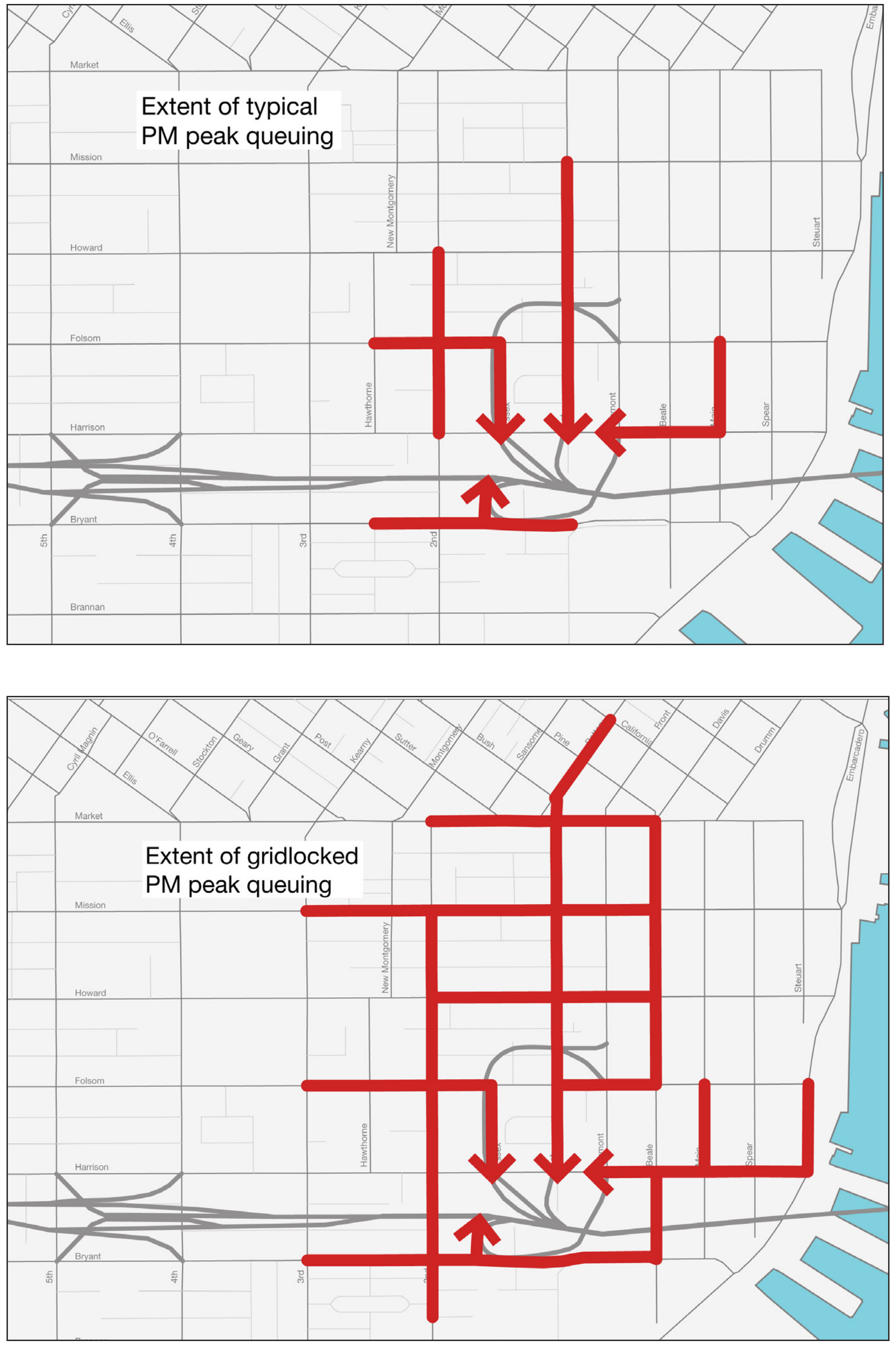

Figure 25: Typical versus Gridlocked Queuing

The character of SoMa has been changing over the years as it has transitioned from a light-industrial area to a mix of commercial and residential uses. The TTC and the San Francisco Planning Department's proposed Transit Center District Plan (TCDP) promise to increase the intensity of development within SoMa, while transforming the street grid into a more locally-focused pedestrian and transit-oriented area.

Balancing the regional and local transportation needs within SoMa is a challenge. The regional needs are related to managing the Bay Bridge-bound vehicle queues on SoMa streets. Local needs are related to accommodating increased transit and pedestrian activity on SoMa streets as redevelopment occurs.

Purpose and Limitations of this Study

The ultimate objective of the SoMa analysis is to identify transportation improvements that better manage Bay Bridge queues and improve local traffic circulation and transit reliability. This study represents a first step towards investigating and understanding the transportation issues in SoMa.

The initial work on a second VISSIM microsimulation model of the SoMa street network east of Fifth Street was advanced as part of this study. The SoMa model utilizes VISSIM's dynamic assignment routine to assign traffic to the network. Dynamic assignment, as applied in this study, is an iterative procedure that adjusts a driver's route choice based on the experienced travel time and cost on the network.

The analysis does have limitations. While the VISSIM model is considered calibrated, further model development work is required before a more comprehensive analysis of the study area is possible. The additional work required to further advance the model includes:

- Refining VISSIM's dynamic assignment routine
- Adjusting the origin-destination (O-D) tables and traffic compositions (SOV, HOV, Truck)
- Understanding the variability in eastbound Bay Bridge traffic operations during the PM peak period
- Understanding the variability in traffic demand across the SoMa study area
- Developing a better estimate of traffic produced and attracted to internal zones
- Adding pedestrian volumes at more intersections
- Developing a future year traffic forecast

A comprehensive analysis of potential improvements has not been conducted because the model requires these additional refinements. However, initial testing of potential improvements has been completed and promising strategies have been identified. The microsimulation model developed for this effort will serve as a valuable tool for further analysis.

SoMa Desired Outcomes

The following desired outcomes will become performance measures when the model is further developed. These tentative performance measures were developed as a result of discussions with the stakesholders:

Congestion:

- Bridge queue on 1st Street/ 2nd Street, and Beale should not extend beyond Howard at any time.
- Bridge queues on 1st Street/2nd Street, and Beale should be reduced in the improvement option (compared to the base alternative).
- The total vehicle-hours/person-hours of delay should be reduced in the improvement option.

Transit Travel:

- Transit travel times on Mission Street, First Street, 2nd Street and and Folsom Street should decrease with any improvement option.

SoMa Analysis

VISSIM Microsimulation Analysis

Model Study Area and Scope

Figure 26 presents the study area for the SoMa PM peak period VISSIM model. The VISSIM model network includes the following:

- 0.75 square-miles of the SoMa street network bounded by Market, Embarcadero, Bryant and Fifth Street
- 80 signalized intersections, including the intersections north of Market Street that provide points of access for traffic entering and exiting the Financial District
- 9 freeway ramps serving I-80 and the Bay Bridge
- All of the major paths of travel between the Financial District and the Bay Bridge.
- All of the major on and off-ramps that serve downtown San Francisco and SoMa
- I-80 is included in the model as an external zone that produces and attracts traffic. However, freeway operations were not explicitly modeled nor included in the calibration
- The existing Transbay Terminal (as of 2009)
- A two-hour PM peak period (includes a one-hour “warm-up” period and a one-hour analysis period)
- VISSIM’s dynamic assignment routine is utilized
- Existing traffic volumes (2008-2010) and existing transit service (as of 2009)
- The PM peak period traffic demand tested in the model represents a typical “functioning” data
- Traffic demand is split into SOV, HOV, and Truck based on recent counts and observations
- 31 external zones on local streets
- 2 external freeway zones (Bay Bridge East and I-80 West)
- 26 internal zones within the study area

While the SoMa area is generally defined as covering a larger area of downtown San Francisco, the model study area was limited to what is shown in Figure 26. This study area is sufficient to capture most of the major commute paths for traffic exiting downtown San Francisco during the afternoon.

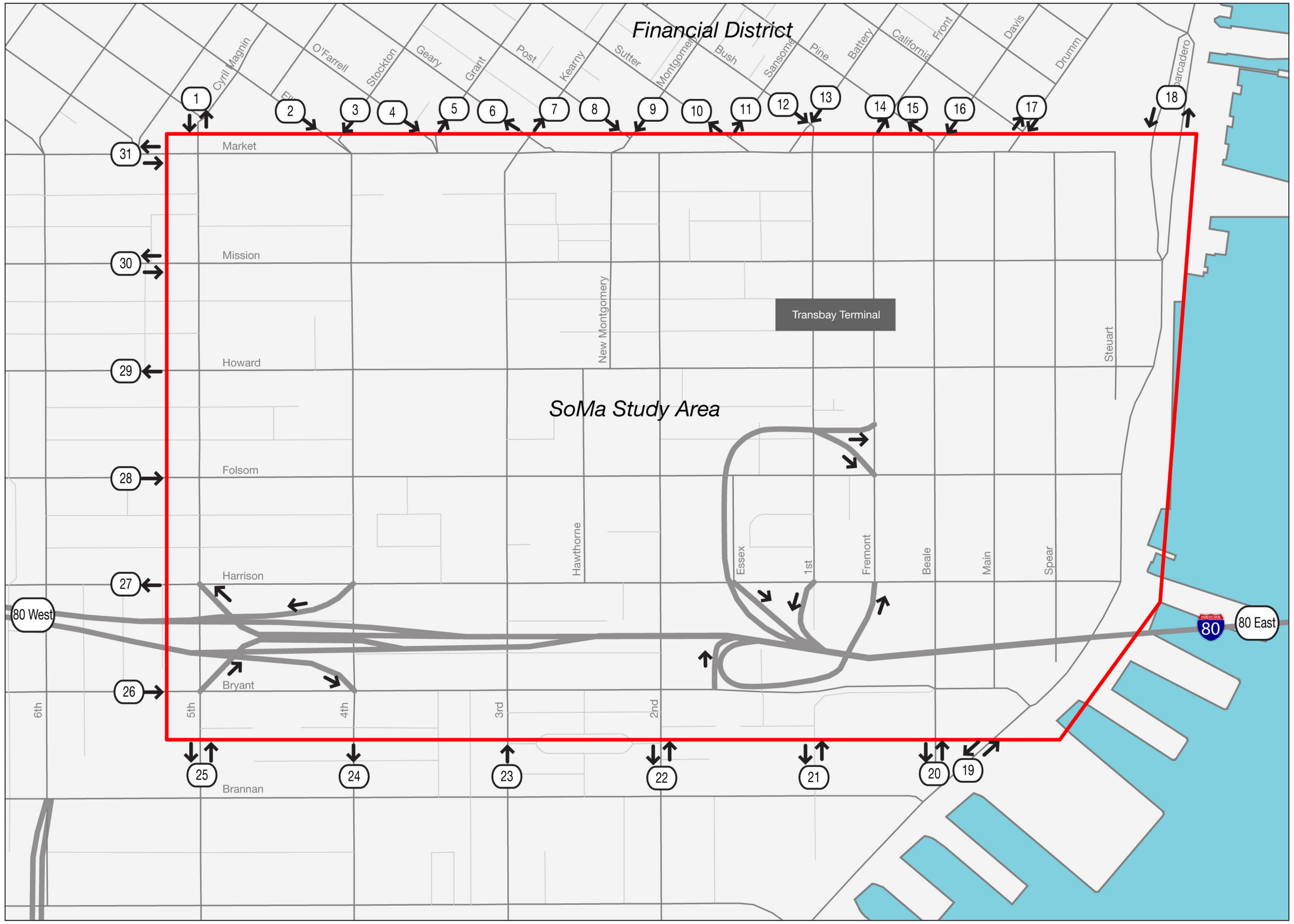

Figure 26: SoMa VISSIM Model Study Area

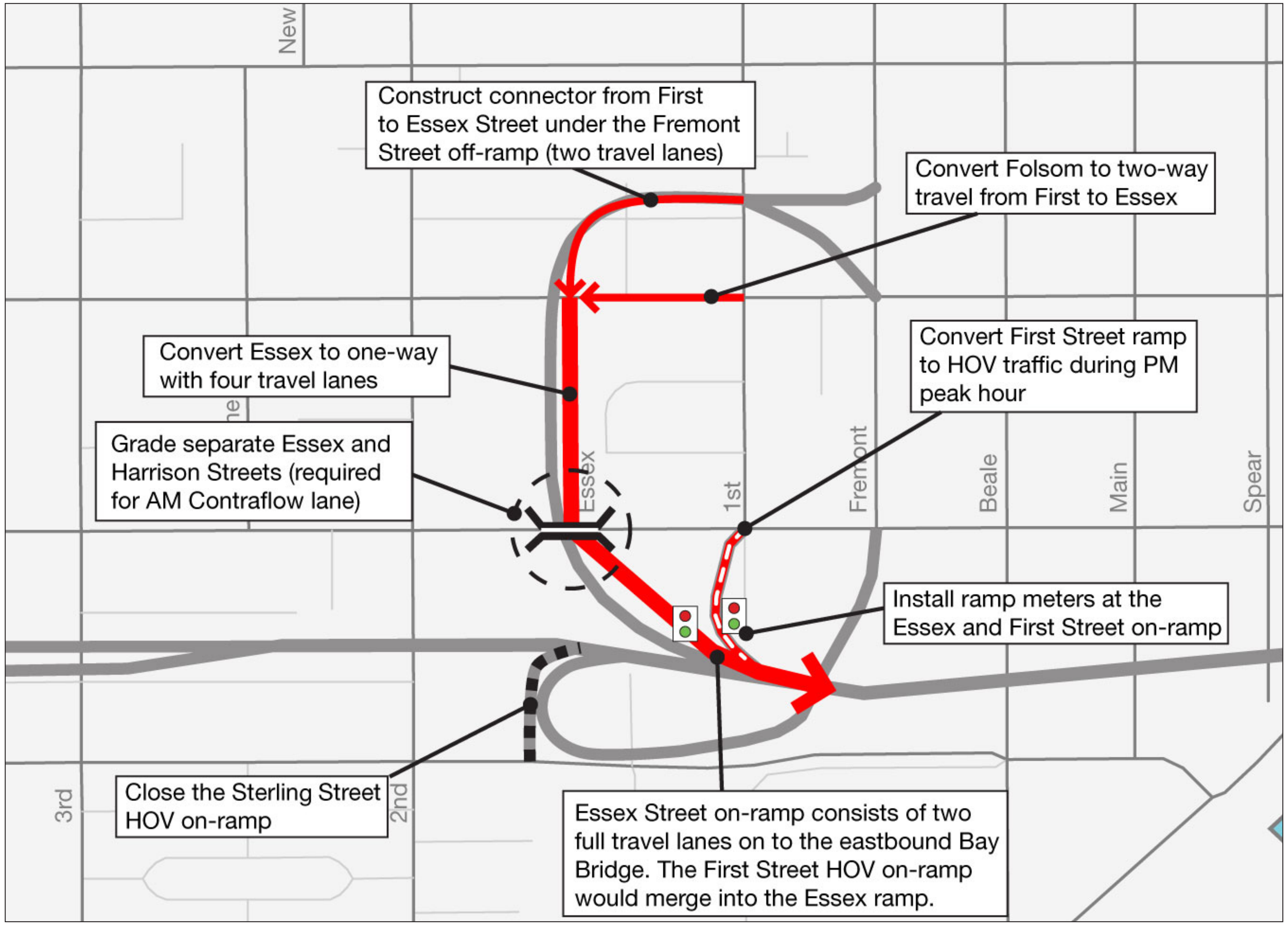

Figure 27: Potential SoMa Improvements

Previous Modeling Efforts

The SoMa VISSIM model developed for this study leverages two previous modeling efforts:

- A detailed Market-Embarcadero VISSIM model developed by Tony Young at the San Francisco Municipal Transportation Agency (SFMTA) for studying signal timing and coordination plans along Market Street and the Embarcadero.
- A VISSIM model of the TTC street level bus plaza developed by Arup for the TJPA that analyzed the operating capacity of the plaza and traffic operations/signal timings along Fremont Street. Traffic operations on streets immediately adjacent to the TTC (Mission, Howard, Second, and Beale Streets) were also included in the analysis.

Both of these VISSIM models analyzed existing traffic demand. Traffic signal timings, field observations, transit information, and pedestrian volumes were all carried over into the SoMa model.

Model Scenarios

The SoMa assessment considers two scenarios:

- **Base Year:** This scenario represents the final calibrated version of the VISSIM model and includes existing traffic volumes, transit service, the existing Transbay Terminal, and the existing roadway network. The existing traffic volumes and origin-destination (O-D) matrices were developed using a variety of traffic counts that were collected between 2006 and 2010. While this represents a long time frame, the most recent traffic volumes collected at the on-ramps in 2010 do not differ significantly from the ramp volumes collected in 2006.

- **Base Year With Improvements:** This scenario analyzes the same base year traffic volumes but includes a set of street improvements that have the potential to better manage afternoon Bay Bridge queues and improve local circulation and transit reliability. The set of improvements is extensive and assumes that the contraflow lane is constructed and in operation. It is also assumed that the grade separation of the Essex Street on-ramp and Harrison Street are constructed. All of these improvements are considered feasible for purposes of this study. Figure 27 presents the improvements.

SoMa Analysis

The set of improvements are summarized below:

- Closure of the Sterling Street HOV on-ramp
- Relocation of HOV's to the First Street on-ramp
- Restrict the First Street on-ramp to HOV traffic only; Essex Street becomes the major on-ramp to the Bay Bridge for auto traffic
- Conversion of Essex Street to one-way southbound (towards the Bay Bridge) and widening of the ramp to four lanes. This increases the storage capacity of Essex Street.
- Grade separating Essex Street at Harrison. Grade separation at this intersection is necessary to construct the AM contraflow lane under Exit Option B.
- Installing metering signals to control traffic entering the Bay Bridge on-ramp at Essex Street.
- Converting Folsom to two-way traffic from First Street to Essex. This provides an additional path for vehicles east of First Street to access Essex Street, since Harrison must provide access.
- Constructing a one-way street with two travel lanes under the Fremont Street off-ramp that connects First Street to Essex Street. This provides an additional path for vehicles on First Street to access Essex Street.

Other changes to the street system proposed by the Planning Department in the Transit Center District Plan (TCDP) were not modeled and are not included in the improvement list.

The analysis presented in this study includes the calibration of the Base Year model with the existing traffic demand and the existing network. A screening of the Base Year and the Base Year with Improvements scenarios was done to compare queuing and the throughput of the Bay Bridge on-ramps.

This study does not consider the impacts of future traffic demand or other circulation changes on SoMa streets. Previous modeling work has indicated that forecasts of future traffic far exceed the capacity of the SoMa transportation system. A discussion of SoMa traffic forecasts is provided in a later section to highlight the significant increases forecast by the SF-Champ's travel demand model.

Dynamic Assignment: Explanation and Rationale

The SoMa model incorporates VISSIM's dynamic assignment routine to model driver's route choice between origin and destination zones in the network. Dynamic assignment, as defined within VISSIM and as applied in this study, is an iterative routine that redistributes traffic between an O-D pair based on the cost experienced by users as they travel within the simulation. VISSIM's dynamic assignment routine has the ability to produce a set of O-D traffic flows that are responsive to queuing and congestion as it develops over time.

VISSIM identifies routes between each O-D pair and assigns traffic to each path based on the travel time and cost experienced by users during a series of simulation runs. Successive iterations of the model employ a search for new routes and O-D traffic is redistributed to routes based on travel costs from previous iterations. The new traffic assignment is loaded on the network, the travel costs are collected during the run, which are then used in subsequent runs. These steps are executed until convergence criteria are met.

VISSIM's dynamic assignment routine differs from standard "static assignment" procedures for modeling traffic flows. Static assignment produces a set of O-D routings and traffic flows that do not change as congestion and queuing develops. As simulation study area's increase in size, it becomes increasingly difficult to specify routes between all O-D pairs and assign a traffic flow to each route. In the SoMa model study arae, static assignment would require identifying and assigning traffic flows to thousands of routes. VISSIM's dynamic assignment routine eliminates the need to do this by generating the routes and traffic flows as it iterates.

The usage of the term dynamic assignment in VISSIM differs from other definitions commonly used in transportation planning. While there is no unified definition, to most transportation researchers and practitioners the term "dynamic assignment" is most often associated with the process of "Dynamic Traffic Assignment" (DTA) in travel demand modeling. DTA in travel demand modeling is a technique for producing an equilibrium solution that is based on experienced travel costs[2]. DTA is a different concept from the microsimulation dynamic assignment routine applied in this analysis.

Model Development

This section details the development of the SoMa VISSIM model. The model development was an iterative process and includes the following steps:

- Step 1: Data collection
- Step 2: Matrix estimation
- Step 3: VISSIM network development
- Step 4: Assign initial O-D matrix on the VISSIM network using dynamic assignment
- Step 5: Run VISSIM multiple times to generate multiple routes and traffic assignments
- Step 6: Compare VISSIM output to calibration criteria
- Step 7: Adjust O-D table and refine VISSIM network
- Step 8: Repeat Steps 5 through 7 until the model is successfully calibrated
- Step 9: Use calibrated model in the scenario analysis

Details on the data collection, O-D matrix estimation, and the steps to calibrate the SoMa VISSIM model are presented in the following sections.

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[2] A Primer for Dynamic Traffic Assignment, ADB30 Transportation Network Modeling Committee (Transportation Research Board, 2010).

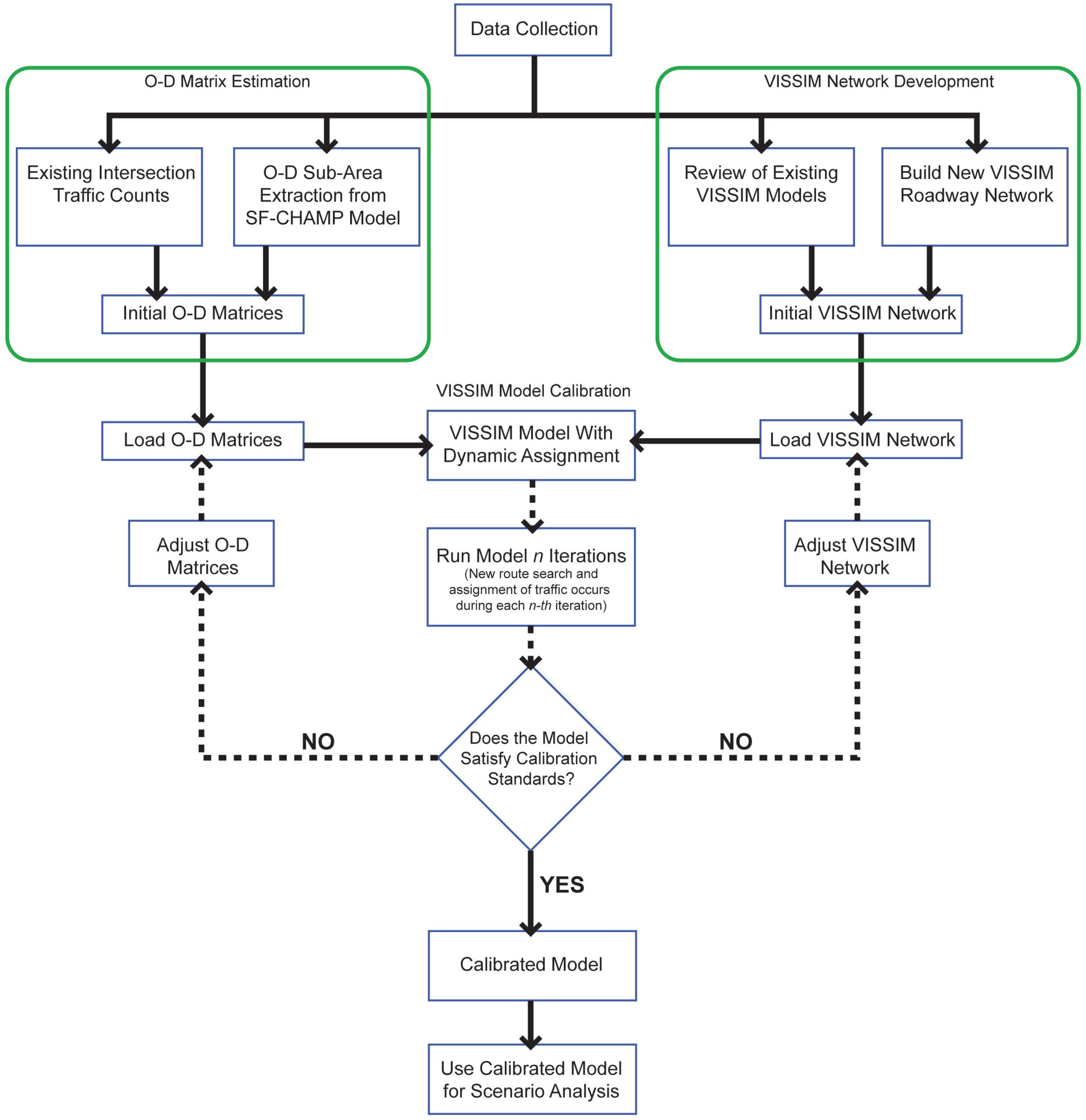

Figure 29: SoMa VISSIM Model Development Process

Data Collection

A considerable amount of traffic, transit, and pedestrian data was compiled from existing sources. Table 20 lists the traffic data sources used to develop the existing O-D matrices:

Study	Count Date	Count Locations Used in SoMa Model	Source
Market-Embarcadero VISSIM Model	2006	Market Street and Embarcadero	SFMTA
Transit Center District Plan	2008	Area bounded by Mission, Third, Bryant, Steuart Streets	AECOM
Eastern Neighborhoods	2010	Area bounded by Harrison, Fourth, Bryant, and Fifth Streets	Fehr & Peers
Other Studies (SF Mint Plaza traffic study, others)	2008–2009	Locations on Fourth and Fifth Streets (between Mission and Folsom)	LCW Consulting
Bay Bridge Corridor Congestion Study	2008–2009	First, Essex, Sterling Street on-ramps; additional vehicle occupancy counts to confirm HOV percentages	Arup

Table 20: Data Sources

The recent traffic counts at the First, Essex, and Sterling on-ramps confirm that traffic levels have not changed to a measurable degree over the last several years. Additional vehicle occupancy counts were also conducted at the on-ramps to confirm the split between SOV and HOV traffic on the ramps.

SoMa Analysis

Origin-Destination Matrix Estimation

The VISSIM dynamic assignment routine requires a set of O-D matrices that correspond to each traffic composition (SOV, HOV, Truck) and each hour of analysis. The O-D tables specify the number of vehicles that travel between a given origin and destination pair. The dynamic assignment procedure identifies a set of feasible routes between a given O-D pair and then assigns the O-D volumes to each route based on the generalized cost.

Estimating an accurate O-D matrix is critical to developing a calibrated model. The O-D matrix estimation process in the SoMa study area is complex for the following reasons:

- Size of the network and the number of zones: The SoMa model contains 64 total zones (external and internal), which makes the O-D table 4,096 cells (64*64).
- Uncertainty related to regional versus local travel: While regional trips to the Bay Bridge are the primary focus of the study, local trips still represent the majority of total traffic on the network at any given time. Estimating the split of Bay Bridge versus local traffic at each origin is extremely difficult. Presumably, a vehicle loading on the network at an origin has already chosen a route that provides the most direct route to its intended destination.
- The intersection traffic counts used for the model reflect the traffic produced and generated from zones external and internal to the SoMa study area network. Turning movement counts at intersections along the edge of the study area can be translated into external origin and destination flows rather easily. However, trips produced and attracted at internal zones require using a travel demand model.
- Balancing the external and internal flows to achieve a reasonable demand matrix

The estimation of the O-D tables was an iterative process:

1. An initial set of origin and destination volumes were developed for each external zone based on the traffic counts.

2. Cambridge Systematics extracted a sub-area O-D table from the SFCTA's SF-CHAMP model that roughly matched the SoMa model area zone structure. This O-D table provided:

   o Vehicle trips produced and attracted by internal zones
   o An initial estimate of the relative flows between O-D pairs

3. The O-D tables were split into SOV, HOV, and Truck matrices based on the following percentages (collected from traffic counts at the Bay Bridge on-ramps):
   o SOV = 75%
   o HOV = 23%
   o Truck = 2%

4. A set of additional rules and adjustments were applied to modify or restrict trips between certain O-D pairs.

5. The zonal origins and destination were factored iteratively to balance the overall O-D table.

6. The O-D tables used with VISSIM's dynamic assignment routine.

7. Based on the VISSIM model output and calibration criteria, the O-D matrices were adjusted to provide a better calibration result (steps 4 through 6). The matrix estimation is referenced in the calibration procedure section presented below.

VISSIM Network Development

The VISSIM network development included the following elements:

- Intersections along Market Street from Fifth Street to the Embarcadero and along the Embarcadero from south of Washington Street to Bryant Street were input from the SFMTA's Market-Embarcadero VISSIM model
- The remaining intersections, approximately 50 locations, were coded
- Traffic signal timings were carried over from previous models (where available) and coded at the remaining locations based on field observations and signal timing plans (where available)
- Bus routes operated by Muni, Golden Gate Transit, and SamTrans
- Pedestrian volumes (where available)
- Conflict areas and priority rules were included to provide right-of-way guidance and reduce the incidences of intersection blocking

Figure 30 illustrates the VISSIM SoMa model.

Figure 30: SoMa VISSIM Network

VISSIM Model Dynamic Assignment Development

VISSIM's dynamic assignment routine is an iterative process that requires various assumptions and actions. The SoMa model dynamic assignment routine includes the following:

- Number of iterations: Multiple runs of the model are required for the dynamic assignment routine to generate enough paths to distribute traffic to. For this analysis, the number of runs was set at 10 (n = 10). The first iteration (n=1), the shortest path between each O-D pair is searched. All traffic is assigned to this route. Each run executes a different random seed. The random seed initializes the random number generator, which provides stochastic variation of input flow into the model.
- Network loading: In early iterations, there are not enough paths to provide a reasonable distribution of traffic on the network. Until the model searches enough paths, applying 100 percent of the traffic will lead to gridlock. Therefore, traffic loading is set at 50 percent of the total for n=1, and is increased in 5 percent intervals until 100 percent of the traffic demand is assigned.
- Evaluation interval: This is a sub-interval where travel time and cost information is collected. In this model, O-D tables are provided on a one-hour basis and the evaluation interval is set at 10 minutes.
- In subsequent iterations, (e.g., n = 2 – 10), additional routes are searched and added. For a given evaluation interval, traffic is assigned to each route based on the experienced travel costs collected during that evaluation interval in previous iterations. A process weights the travel costs for a given evaluation interval across the previous iterations.

Model Calibration Criteria and Actions

The calibration of the SoMa VISSIM model focused on two criteria:

- Achieve a GEH statistic of 5.0 on three of the four SoMa study area Bay Bridge on-ramps: First, Essex, Sterling, and Fifth. These four on-ramps act as a screenline for traffic exiting downtown San Francisco and destined for the East Bay.
- Replicate queuing conditions on First Street, Essex Street, and Harrison Street that match field observations.

The following actions were taken to calibrate the SoMa VISSIM model:

- Adjusted relative traffic flows between O-D pairs
- Adjusted signal timings
- Add surcharges to discourage certain turning movements. This makes other slightly longer routes more attractive in VISSIM.

Calibration Results

Table 21 summarizes the calibration results for the Bay Bridge on-ramps.

SoMa Bay Bridge On-Ramp	Observed	Model	GEH
First Street	2,024	2,126	2.22
Essex Street	1,590	1,753	3.99
Sterling Street (HOV)	1,117	732	12.7
Fifth Street	876	766	3.86
Total to Eastbound Bay Bridge	5,607	5,377	3.11

Source: Arup, 2010

Table 21: SoMa Calibration Results

- The calibration at the two main Bay Bridge on-ramps, First and Essex Streets, have a GEH statistic less than 5.00
- The total volume the model sends to the eastbound Bay Bridge is slightly less than the observed counts. However, the model difference, as measured by the GEH statistic of 3.11, is less than the GEH standard of 5.00
- The overall distribution of traffic between the four on-ramps approximates the proportions indicated in the observed ramp counts

The model is less effective at estimating the HOV traffic to the Sterling Street on-ramp. Possible explanations for this include:

- The model appears to be over-assigning HOVs to First and Essex Streets
- The O-D table requires further refinement to assign more trips from the south edge of the model (Bryant, Second, and Third Street origins) to the Bay Bridge. This would send more HOV trips towards Sterling Street.

While the calibration of the model to vehicle throughput at the ramps is important, replicating the queuing upstream of the ramps is the primary focus of the study. Calibrating the model to queuing was done by reviewing the extent of vehicle queues observed in the simulation run and comparing that to field observations. Figure 31 shows snapshots of queuing during the simulation period at several critical locations. Additional data collection is advisable to better measure existing queue lengths.

The process described above indicates that the SoMa PM peak period model is calibrated for this level of analysis. As stated earlier, further refinements to the model are required.

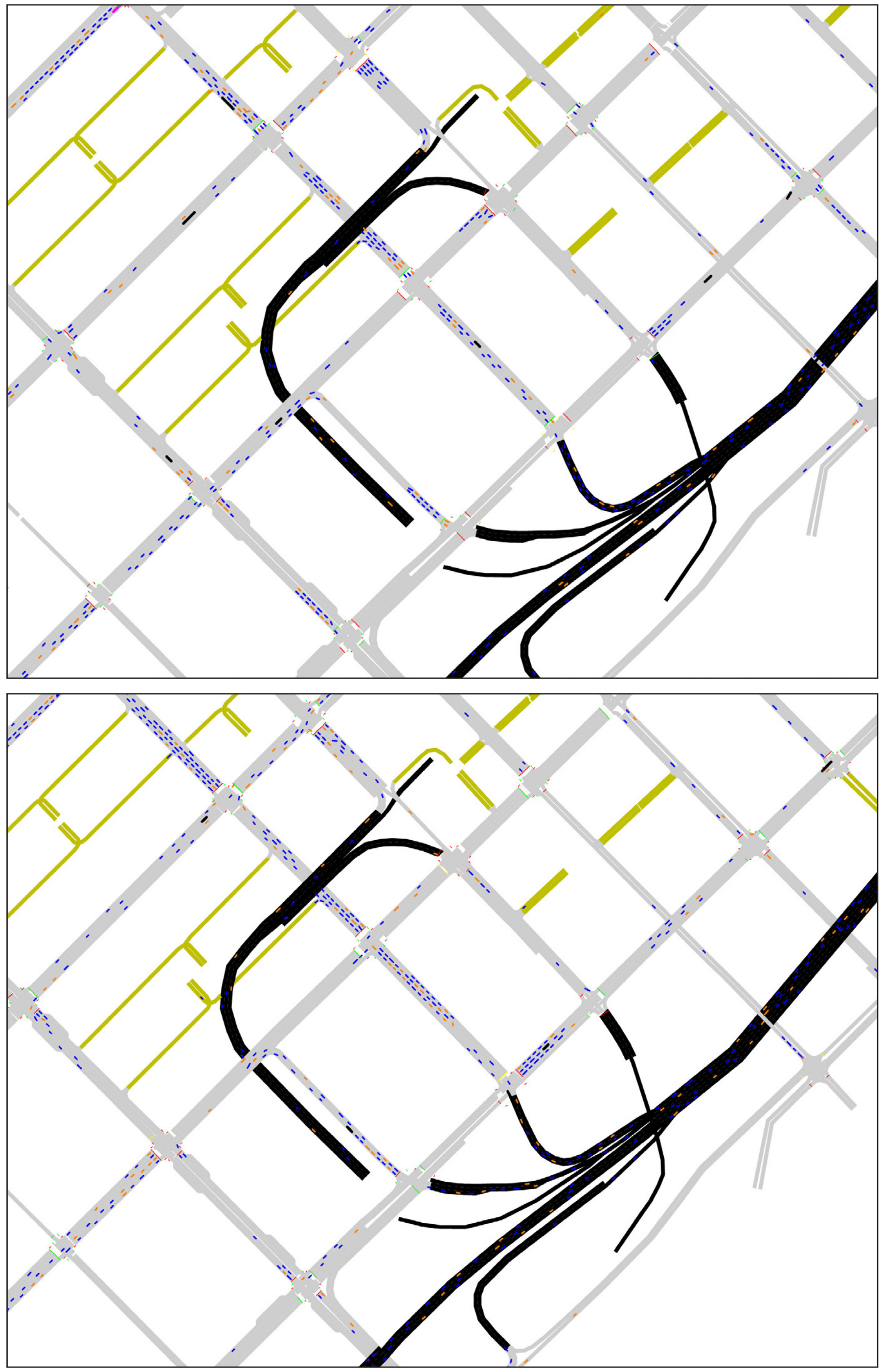

Figure 31: Vehicle Queuing at the end of the PM Peak Hour Simulation Model

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SoMa Analysis

Scenario Evaluation

The two scenarios, Base Year and Base Year With Improvements, were analyzed in VISSIM for the two-hour PM peak period. No performance metrics were generated. A screening of the two scenarios was done to compare queuing and the throughput of the Bay Bridge on-ramps.

Observations from the VISSIM model runs of the Base Year and Base Year with Improvements scenarios are summarized below:

- The improvement options have the potential to enhance afternoon access to the Bay Bridge, while also maintaining or enhancing circulation on local streets for transit and local vehicular traffic
- The closure of the Sterling Street HOV on-ramp and the relocation of the HOV access to First Street warrants further study.
- The queue storage at Essex appears adequate with the recommended widening to four lanes and the addition of the two-lane connector under the TTC bus ramps between First and Essex. Traffic along Folsom gets slightly worse in this scheme and will require further improvements to help manage traffic entering Essex from Folsom.
- The grade separation of Essex will require some form of metering to control traffic flow onto the new two-lane on-ramp.
- The new First Street HOV on-ramp will likely require a ramp meter. The First and Essex Street on-ramp meters should then be coordinated to allow for a safe and orderly merge of traffic flows from the two ramps. Without any metering, the HOV traffic entering from First Street could have difficulty merging into the flow of traffic.

This screening was done to begin the investigation of possible solutions. Further work is required to test and optimize any potential improvements.

Major Findings

The SoMa afternoon analysis presented in this study accomplished the following:

- Completed a calibrated microsimulation model of the SoMa area in downtown San Francisco. The model utilizes dynamic assignment to study PM peak period traffic conditions on local streets and ramps serving the Bay Bridge
- A reconfiguration of the Bay Bridge on-ramps and streets feeding these ramps can improve regional access to the bridge and local transit circulation; 5th Street ramp, for example, is well below capacity
- SOMA traffic is impacted by the lane configuration of the eastbound west approach and Bay Bridge. Further studies should also consider changes to the Bridge flow in coordination with SOMA improvements
- The SoMa model will serve as a valuable tool for future study of land use and transportation alternatives within the study area

Further Study

Introduction

This analysis illustrates the need to maintain bus transit travel times and reliability on the Bay Bridge corridor. A number of potential physical and operating strategies, including a contraflow transit lane, appear promising based on the preliminary analysis presented in this study.

Further study is suggested for the contraflow concept, but should carefully consider the conflicting impacts and issues:

- Bus transit enhancements
- Additional vehicle access into San Francisco
- Distribution of those vehicles in downtown versus beyond downtown
- HOT revenue potential
- Impact of those vehicles in the afternoon on freeway and downtown street operation
- Impact of the contraflow lane on morning eastbound traffic, both on the Bridge and on access to the Bridge
- Impact of freeway metering on westbound traffic
- Impact of Treasure Island development
- BART capacity
- Impact of proposed bicycle lane
- Impact on Bridge maintenance activities
- Morning goods movement needs
- Ability of the City to manage afternoon Bridge-bound traffic queues
- Design of the eastbound West Approach and its impact on traffic flow, both on Bridge on the City streets
- Urban design impacts on City streets of alternatives
- Additional congestion pricing to manage queues and increase LOS
- Cost of improvements and construction and operational feasibility

Further investigation could be an opportunity to actively manage the limited system capacity proactively and transparently. It could also lead to important improvements that benefit both regional travel and local conditions in San Francisco. However, for the benefits to be greater than the impacts requires careful thought and considerable discussion and collaboration with multiple stakeholders.

This study has added to our understanding of future year conditions at the Toll Plaza and also South-of-Market in their respective peak periods. As a result, it appears warranted to proceed with additional investigation of improvements to the Bay Bridge Corridor. Further studies should be comprehensive and investigate improvement options as a system.

As a starting point, further study should include the following work elements:

Policy and Priority Understanding

While San Francisco has accommodated substantial job growth over the last 30 years, that growth has absorbed most of the available capacity in the transportation system – including BART's ability to operate longer trains and more trains, or the Bay Bridge's ability to carry more people through carpools and buses. With another 250,000 jobs projected in San Francisco over the next 25 years, and with about 40 percent of those jobs held by East Bay residents, BART and the Bridge will like move an additional 100,000 workers into San Francisco daily. As BART reaches capacity, a revisiting of the Bridge's functions should be considered.

Survey of Best Practices

This study mentions several highway facilities that provide preferences for buses and HOVs including the Lincoln Tunnel in New York and New Jersey. There are other examples, and to provide decisionmakers with a robust understanding of the universe of operational options, further studies should provide additional detail and also arrange field trips to see these facilities and discuss their operations with staff. Among the freeways to consider investigating are the Lincoln Tunnel (and the Port Authority Bus Terminal), San Diego's I-15 Managed Lanes, the LA Silver Line (Harbor Transitway and El Monte Busway), the Champlain Bridge in Montreal, I-30 in Dallas, and the Shirley Highway in the Washington DC area.

Study of Alternatives – Transit and Overall Corridor Demand

The Bay Bridge is an important part of the infrastructure system that connects San Francisco to the East Bay. Our understanding of the relationship between transit demand and capacity and highway demand and capacity has increased in recent years, but any further study of the use and demand of additional peak period westbound capacity will need to be framed by BART's available capacity.

A robust demand forecasting exercise which analyzes the peak period capacity constraints relative to total demand is vital to both our understanding of the corridor and required for any outside financing.

Suite of Alternatives – Westbound Study

Additional Westbound HOV Facilities

Caltrans has designed the Bay Bridge access system to allow HOVs to bypass queues either on the mainline freeways or at the Toll Plaza by using dedicated HOV bypass lanes and ramps. Two significant gaps exist in this network:

- West Grand/Maritime on-ramp
- I-580 to SR 24

Prior to the Loma Prieta earthquake, the West Grand/Maritime on-ramp included a HOV lane that extended to the beginning of the ramp at Maritime. When the ramp was rebuilt after the earthquake, the HOV lane was designed to begin at its junction with I-880 (about 2,000 feet west of Maritime). During peak periods, the ramp is congested and buses using it are delayed by up to 10 minutes. Expanding the ramp to extend the HOV lane to Maritime has been identified as a critical improvement several times, and was even included in the RM2 legislation, but the project did not advance. AC Transit has considered operating a Transbay Bus Rapid Transit route via MacArthur and West Grand to the Bridge, but reliability suffers without a dedicated HOV lane on the Maritime ramp.

As with the Maritime ramp, westbound HOV and bus traffic on I-580 is the only freeway that lacks a HOV lane outside of the distribution structure. Extending a westbound-only HOV lane could save up to 20 minutes of travel time for HOVs and for buses in the corridor, which will become critical as traffic increases and freeway travel times slow. During the peak hour about 15 buses use I-580.

Further Study

Contraflow Lane on Bay Bridge westbound

As traffic increases in the system, absent additional capacity, Caltrans can either choose to allow traffic to queue further back on the East Bay freeway system or it can increase the metering rates and effectively move the queue from the Toll Plaza and the freeways onto the Bridge. In the first case, all traffic is impacted, including those vehicle not destined for the Bridge. In the later case, the HOV/bus time advantage degrades, since the Bridge will operate at a reduced speed.

A contraflow lane on the Bridge could operate in several configurations. It is recommended that two approaches be considered in further studies. In Option 1, the contraflow lane would be an extension of the HOT network. Buses (up to about 300 per hour) and tolled vehicles would use the lane for direct access into San Francisco. The toll would be adjusted to ensure the lane operated slightly below capacity to ensure good service and fast speeds. HOVs would continue to use the existing HOV bypass system. Under this option, VISSIM simulations indicate that the Bridge queue is about the same in 2035 as today. The downside is that additional private vehicles enter San Francisco in the morning peak, and likely leave in the afternoon peak.

In Option 2, private passenger vehicles would not be permitted, but trucks would be allowed to use the contraflow lane along with buses. Option 2 would result in less additional capacity into San Francisco, but would improve travel time and reliability for buses and trucks.

In this option, there would be a slight increase in Bridge capacity, since about 200 trucks per hour would be eliminated from the westbound direction, possibly creating additional capacity for another 500 peak hour autos. Since buses would be operating relatively free-flow in the contraflow lane, Caltrans has greater flexibility adjust the metering rates to keep the queue upstream of the toll plaza to reasonable lengths.

Any contraflow analysis should also consider the impacts on the morning eastbound traffic. Currently, about 6,500 vehicles use the Bay Bridge eastbound in the highest morning peak hour. Any future analysis should consider morning eastbound traffic conditions impacts resulting from the removal of one traffic lane.

In addition, the impact on Bridge maintenance (where Caltrans crews often close a lane to work on the Bridge) should also be considered.

Suite of Alternatives – Eastbound Study

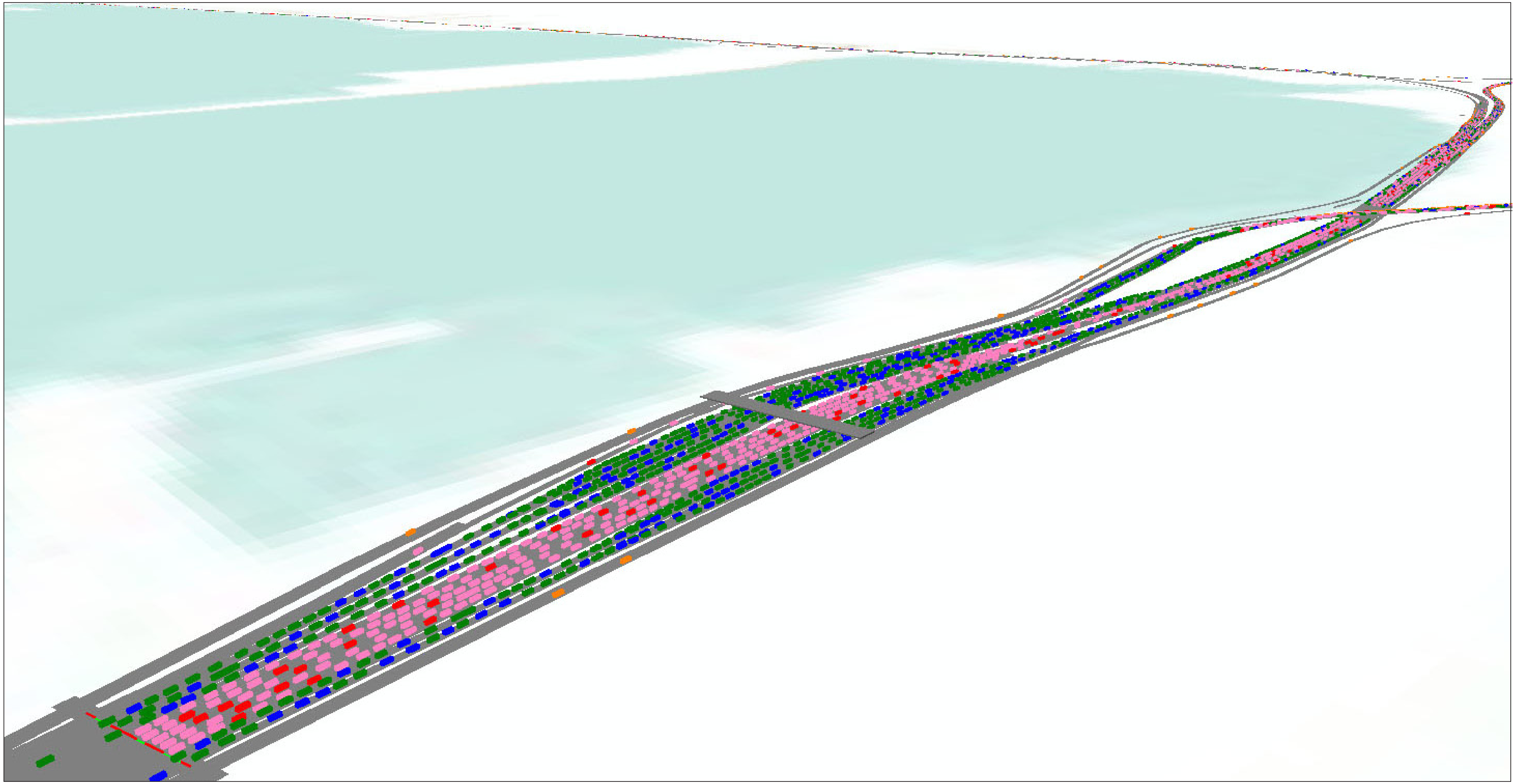
The addition of a contraflow lane on the Bay Bridge would create additional capacity into San Francisco. The use of the contraflow lane as a HOT facility could deliver an additional 1,000 vehicles per hour into downtown. This could increase demand in the PM peak for the return trip to the East Bay, which could increase the amount of traffic queuing on SoMa streets trying to access the Bay Bridge on-ramps. A series of additional questions warrant further investigation in SoMa:

- Future studies should consider whether reconfiguring the eastbound travel lanes at the West Approach to the Bay Bridge. These could include realigning lanes and reconfiguring ramps.
- Closing Sterling Street Ramp, improving Essex Street ramp, converting First to HOV only
- Closing Essex Street ramp and reconfiguring the Bridge so that Sterling ramp has its own lane, converting First to HOV only
- Closing upstream ramps and reconfiguring the 101-80 Freeway so that 8th Street eastbound enters from the right, allowing the Fifth Street ramp to enter its own lane
- Using congestion pricing in the eastbound direction to manage queues and keep streets clear
- Studying the urban design impact of the various SoMa alternatives

Study of Alternatives – Implementation Options

As a plan is developed and the benefits, primarily ridership and time savings, are better understood, the next study should investigate the best option to deliver whatever improvement is selected. Project risk and project financing could lead to a traditional design-bid-build process financed by tolls charged on the contraflow lane, or it could lead to an alternative approach using a public-private partnership. All options should be considered as the project scope and its risks become clearer.

Further Study



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