Bus on Shoulder Project
SR-94 and I-805

Concept of Operations (ConOps) and User Needs (Deliverables 4.2 and 4.3)

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1 INTRODUCTION

The objective of this Project is to deliver an innovative Pilot demonstration of Bus-on-Shoulder (BOS) operations on a limited access freeway using state-of-the-art technology for driver assistance. The BOS Pilot demonstration will demonstrate that bus performance can be improved by allowing buses to drive on the freeway shoulder with minimal changes to the roadway. The driver assistance technology package includes vehicle-to-roadside communications for improving safety at entrance ramp merge locations. The Pilot project will extend along Interstate 805 (I-805) from Chula Vista/South Bay to State Route 94 (SR-94) into downtown San Diego in both directions of travel. The Project is being conducted as a partnership among the Metropolitan Transit System (MTS), the California Department of Transportation (Caltrans), the U.S. Department of Transportation (USDOT), and SANDAG.

1.1 Purpose of this Document

The purpose of the Concept of Operations (ConOps) is to describe the characteristics of the BOS system from the perspectives of the various stakeholders and identify the major systems, technologies, and infrastructure changes needed for implementation. The ConOps also describes the organization, mission, and objectives of the project.

1.2 Context of this Document

The ConOps describes both non-technology operations and technology (ITS) elements of the deployment. The ConOps is followed by the development of the system requirements, PS&E, and procurement documents. This document contains both technical and non-technical descriptions of the following Project elements:

- The project stakeholders, along with their respective roles and responsibilities
- Existing conditions and systems
- The operational needs and project concept
- Modifications and changes to existing systems and new systems
- Modifications and changes to the existing operations and support environment
- Operational scenarios

1.3 Project Overview

The Project is envisioned to deliver an innovative demonstration of Bus on Shoulder operations on seven miles of existing freeways using state-of-the-art technology for driver assistance. The Project is anticipated to improve schedule reliability by allowing authorized transit buses to drive on the freeway shoulder, during specific operating conditions, with minimal physical improvements to the roadway. The Project will be deployed along Interstate 805 (I-805) between State Route 54 (SR-54) and State Route 94 (SR-94), and along SR-94 between I-805 and downtown San Diego.

Along I-805, South Bay *Rapid* vehicles will utilize the outside shoulder in both the northbound and southbound directions between SR-54 and SR-94. Where auxiliary lanes are available, the preference will be to use the auxiliary lane instead of the shoulder; this does not preclude the use of the shoulder

but emphasizes the use of the auxiliary lane. On the connector between northbound I-805 to westbound SR-94, buses will use a widened, restriped outside shoulder onto SR-94. Along westbound SR-94, between State Route 15 and Interstate 5, buses may travel along the inside shoulder into downtown San Diego. The Rapid 235 will also have the opportunity and potential to use the BOS lanes in the future.

Prior to the connector between eastbound SR-94 to southbound I-805, the buses may utilize the outside shoulder to access the connector onto southbound I-805. Minor improvements to the existing shoulders may be required, such as re-striping, signage, drainage, shoulder pavement improvements, and minor widening in limited locations. Improvements are expected to be entirely within the existing freeway right-of-way.

The Project will focus on BOS operations during periods of traffic congestion at slow operating speeds. MTS *Rapid* vehicles may utilize designated freeway shoulders when freeway speeds fall below 35mph, and may travel up to 15 mph faster than the adjacent general-purpose lane not to exceed 35mph. Based on existing traffic conditions, bus on shoulder operation is anticipated to occur on a daily basis, Monday through Friday, between 6:00 AM to 9:00 AM (northbound/westbound) and 3:00 PM to 6:00 PM (eastbound/southbound). Buses may also use shoulders in the event of traffic congestion resulting from an incident or weather event. Four to six buses per hour are anticipated to operate in the shoulder during the periods defined above. Operating guidelines will be developed as part of the project.

The Project is expected to utilize technology to enhance operation of the South Bay *Rapid* service, including: lane departure warning, blind spot warning, forward collision warning, and ramp metering transit priority technologies. The in-vehicle technology package will include:

1. Lane Departure Warning (LDW) system that will alert (audio, visual, and/or haptic) bus drivers that they are drifting into an adjacent lane;
2. Blind Spot Warning (BSW) system that will alert bus drivers of vehicles in the bus blind spots;
3. Forward Collision Warning (FCW) warning system that will alert bus drivers of forward obstructions;
4. Ramp metering Transit Signal Priority (TSP) utilizing vehicle-to-roadside communications that will hold vehicles at each existing ramp meter along the corridor allowing an approaching bus to travel through potential conflict points;
5. Bus trajectory tracking system (Probe Data Messages: PDM) that will record bus location performance, safety, and lane level road surface conditions on each trip

These technologies will enhance safety by mitigating conflicts between buses and obstructions, vehicles, and emergency responders along the corridor.

2 REFERENCED DOCUMENTS

Following is a listing of documents referenced for the development of this Concept of Operations:

- South Bay *Rapid* Bus on Shoulder Demonstration Fact Sheet; SANDAG; June 23, 2015.
    - A fact sheet providing a high-level overview of the SR-94/I-805 Bus on Shoulder proposal.
- Draft ATDM Strategies (Deliverable 5); I-805 South Active Traffic and Demand Management (ATDM) Project; Kimley-Horn Associates (under contract to SANDAG); December 2015.
    - A draft project deliverable for the I-805 South Active Traffic and Demand Management (ATDM) Project that provides an overview of potential ATDM strategies for use in the I-805 South Corridor.
- Transit Cooperative Research Program (TCRP) Report 151; A Guide for Implementing Bus On Shoulder (BOS) Systems; Sponsored by the Federal Transit Administration (FTA); 2012.
    - *TCRP Report 151: A Guide for Implementing Bus On Shoulder (BOS) Systems* provides guidelines for the planning, design, and implementation of BOS operations along urban freeways and major arterials. The guide was developed through a review of literature, analysis of existing installations, interviews with agency staff involved in BOS projects, and feedback from bus passengers and bus drivers in communities where BOS systems are or were active.
- Project Development Team Charter; Bus on Shoulder Demonstration Project SR-94 AND I-805; Adopted March 2016.
    - The Project Development Team Charter provides information on roles and responsibilities of the project team, and indicates commitment to execute and complete the project.
- Caltrans Memorandum – Subject: Decision Document- Authority for Use of Freeway Shoulders by Transit Buses; June 16, 2008.
    - This Memorandum provides guidance on decision making related to implementation of bus on shoulder operations on freeways in California.
- Use of Freeway Shoulders for Travel – Guide for Planning, Evaluating, and Designing Part-Time Shoulder Use as a Traffic Management Strategy.
    - This guide covers planning, design, implementation, and day-to-day operation of shoulder use. It covers a wide variety of design and operational concepts for shoulder use, and describes how a performance based practical design (PBPD) process guides the planning of facilities with shoulder use.

      Note: this document was provided after development of the ConOps.

- Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) Concept of Operations. FHWA-JPO-13-063.
    - This concept of operations describes a suite of connected vehicle applications for enhancing emergency response, including the concept of communicating information to a Computer Aided Dispatch System operated by a Public Safety agency.
- SAE J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary, March 2016.
    - This SAE Standard defines standards of data messaging for connected vehicle applications.

3 EXISTING CONDITIONS

The proposed Bus on Shoulder operations will be implemented as part of a new bus service. The new service will be known as South Bay *Rapid*, and will include 12 stations along the 26-mile route (15 stations at full build out). The service will operate between the U.S.-Mexico port of entry at Otay Mesa at the south end of the route, and Downtown San Diego at the north end of the route. South Bay *Rapid* vehicles will travel north on SR-125 from the Otay Mesa border crossing, then west through eastern Chula Vista, then north on I-805, then west on SR-94 into Downtown San Diego. South Bay *Rapid* will have a direct connection to the carpool lanes on I-805 via a Direct Access Ramp (DAR) at East Palomar Street, approximately six miles south of the proposed shoulder running area of I-805.

3.1 Project Geography and Partners

The project area is described as SR-94 between I-5 and I-805; and I-805 between SR-54 and SR-94. The SR-94 portion of the project area is located entirely within the city of San Diego. The I-805 portion of the project area passes through the City of National City, the City of San Diego, and two small unincorporated islands of the County of San Diego. Figure 1 shows the project area.

Figure 1. SR-94 / I-805 Bus on Shoulders Project Area

The three primary project partners, responsible for project planning, design, and implementation are the San Diego Association of Governments (SANDAG), Caltrans District 11 (and Headquarters), and the San Diego Metropolitan Transit System (MTS). The U.S. Department of Transportation (USDOT) and Federal Transit Administration (FTA) will provide grant oversight. National City and the City of San Diego will likely be responsible agencies, and are invited to participate in the project development and deployment process, and to provide comments on project deliverables since the project scope includes the ramps between the city streets and the freeway. The California Highway Patrol (CHP) will have an ongoing role in the development of the project.

3.2 On-bus technology

MTS buses currently do not have any driver assistance technologies (LDW, BSW, FCW, or TSP). MTS buses have an industry-standard AVL system that reports bus location back to the transit operations center approximately once per 90 seconds on the data channel of the radio system. The radio system is primarily utilized for audio communications between dispatchers and bus drivers. All 600 buses in the MTS fleet are equipped with the AVL technology. The bus tracks its location on a much higher frequency basis using conventional GPS with commercial grade resolution. Bus drivers can receive text messages from dispatch and supervisor personnel via a mobile data terminal (MDT). Bus drivers can call dispatch and supervisor personnel with an over-the-air voice system. Interaction with the MDT nor phone is allowed by bus drivers when the bus is in motion. No additional interaction with devices (pushing buttons, acknowledging messages, etc.) is allowed by the driver per the Collective Bargaining Agreement (CBA), or advisable due to the potential for distracted driving.

3.3 Ramp Metering System

In the I-805 section of the proposed project there are four metered entrance ramps that the bus will pass while driving on the shoulder northbound:

- Plaza
- 43rd
- 47th
- Imperial

Each of these ramps currently has a ramp meter that controls the flow of vehicles onto I-805. All ramp meters are controlled by 170-controller hardware in 332-cabinets. There is very limited additional space available in the cabinets for new equipment. All of the ramp meters are operated by Caltrans District 11 using the San Diego Ramp Metering System (SDRMS) firmware (version 7.12 or 7.22 depending on whether the ramp has 2 or less lanes (7.12) or 3 lanes (7.22)). Communications to each ramp is via multi-drop serial communications. Caltrans currently operates the meters during rush-hour time periods (6am-9am, M-F). The meters are dark (off) at all other times of day and on the weekend. The metering rates at the ramp are responsive to the measurement of freeway volume and occupancy on loops that are just upstream of the ramp entrance. There are 15 assignable rate levels in the 170 firmware, assignable in number of cycles per minute. The most restrictive possible ramp metering rate is 4 cycles per minute (approximately 13 seconds of red and 2 seconds of green). There is no current requirement for the ramp meter firmware to be able to respond to any external request for priority or preemption.

Extinguishable message signs upstream of each meter indicate to approaching motorists if the ramp meter is operating. If the message sign is dark, the meter is not currently in operation. Status reporting of the ramp meter back to the Advanced Transportation Management System (ATMS) includes the 30-second summaries of volume and occupancy on the freeway mainline, the current operating cycle, errors, violation and passage counts in each lane, and two checksums. Operational reports available to Caltrans staff from the ATMS regarding ramp meter operation include historical data on the metering rates, errors, and volume and occupancy at each ramp.

Caltrans District 11 has installed a 2070 controller in two corridors with the Caltrans Universal Ramp Metering System (URMS) software (new State-wide standard): one on I-5 at Sorrento Valley entrance ramp to control a 4-lane ramp (3 mainline lanes and one transit bypass lane and in the I-15 corridor as part of the I-15 Integrated Corridor Management Project. When a bus arrives in the bypass lane over an inductive loop, the transit signal indication is turned green and all other lanes are held in red until the bus proceeds past a check-out loop after the limit line.

In the southbound direction the bus will pass the following entrance ramps:

- Market
- Imperial
- 47th
- 43rd
- Plaza

These ramps are not currently metered. Plaza is currently under construction for metering installation. Market, Imperial, and 47th are planned for future metering.

3.4 Freeway-to-freeway metering system

The connection from I-805 to SR-94 westbound is metered by Caltrans to smooth the merging flows. This location also uses the same firmware and hardware as the other ramp locations and implements the same operation policies.

3.5 Traveler information

There is one changeable message sign (CMS) visible in the northbound direction and none visible in the southbound direction in the BOS operating area. Caltrans District 11 displays messages on these signs for congestion management (warning of upcoming incidents), traveler information (travel times), and emergency management (amber and silver alerts). Messages are put on each sign based on a sign library of pre-built messages as well as "fill in the blank" messages for Amber and Silver alerts. Ad-hoc, free-form messages are not commonly displayed. There is currently no library of messages that would inform motorists of BOS and no current method for such messages to be displayed on CMS signs in an automatic fashion. SANDAG operates a regional 511 website and phone service that informs motorists of regional events, incidents, construction, and travel conditions. Travel conditions monitoring includes traffic speeds on regional freeways and arterials, camera images from Caltrans CCTV. Caltrans sends tweets from @SDCaltrans to regional motorists that subscribe to the Twitter handle.

3.6 Data sharing

SANDAG operates a regional data hub that receives status messages from Caltrans Advanced Transportation Management System (ATMS), Caltrans RMIS, MTS transit operations, Regional Arterial Management System (RAMS) for signal operations, and can send commands to associated arterial signal systems, ramp meters, and Caltrans ATMS operators using National Transportation Communications Information Protocol (NTCIP) Center to Center methods. The regional hub is a central clearinghouse for operational transportation data for the San Diego region which is utilized to support

regional 511 activities, interagency data sharing, and performance management of the multimodal transportation system. To support performance monitoring and management, SANDAG has partnered with Caltrans headquarters to enhance and expand, the Caltrans Performance Measurement System (PeMS). Through integration with the regional data hub and development of analysis tools, the Caltrans PeMS has been enhanced to include the transit (t-PeMS) and corridor (c-PeMS) modules. These modules, developed in coordination with regional project partners MTS and the I-15 Project Development Team, have established performance monitoring tools to investigate, among other items, the operations of the arterial signal systems and transit on-time performance.

3.7 Shoulder Infrastructure

For context, the project area is located:

- I-805 between SR-54 (post mile 9.0) and the I-805/SR-94 interchange (post mile 13.5), and
- SR-94 between the I-805/SR-94 interchange (post mile 4.0) and I-5 (post mile 1.8)

Table 1 Existing Pavement Sections

Highway	Year Constructed	Post Mile	Shoulder Pavement Section
NB & SB I-805 Outside Shoulder	1971-1973	9.0 – 12.4	0.30' asphalt concrete 0.45' aggregate base 1.25' variable depth aggregate subbase
	1975	12.4 – 12.7	0.3' asphalt concrete 0.8' aggregate base 0.75' variable aggregate subbase
	2001	9.0 – 13.6	0.1' cold-plane and overlay asphalt concrete
NB I-805 Outside Shoulder	2014	9.5 – 10.2	0.9' jointed plain concrete pavement 0.25' hot mix asphalt 0.65' aggregate base 0.75' aggregate subbase
SB I-805 Outside Shoulder	1989	12.0 – 12.3	0.30' asphalt concrete 1.20' aggregate base
	1989	12.3 – 12.4	0.35' asphalt concrete 1.45' aggregate base

	1993	11.4 – 11.9	0.30’ asphalt concrete 1.15’ aggregate base
	2014	9.9 – 10.4	0.55’ hot mix asphalt 2.15’ aggregate base 0.75’ aggregate subbase
WB SR-94 **Inside Shoulder**	1958	1.8 – 3.3	0.25’ plant mixed surface 0.45’ untreated base
	2004	1.8 – 3.3	0.33’ cold-plane and overlay asphalt concrete
EB SR-94 **Outside Shoulder**			0.33’ “selected material” 0.42’ untreated base material
	2004	1.8 – 3.3	0.10’ cold-plane and overlay asphalt concrete

Proposed structural improvements I-805

Based on traffic index calculations performed for the existing pavement, the pavement structure on the outside shoulders of I-805 is sufficiently strong to bear the loads that will be exerted upon it throughout the life of the three-year demonstration project. However, the pavement structure on the inside shoulder of SR-94 will not be sufficient to handle these loads.

Pavement mitigation treatments have been identified with the assistance of Caltrans staff. On I-805, the asphalt paved segments of the right shoulder will be overlaid with 0.1’ of asphalt concrete to improve the smoothness of the ride. Additionally, this cold-plane and overlay will provide the opportunity to increase depressed area around inlets by varying the thickness of the overlay to clear the shoulder of draining water more quickly.

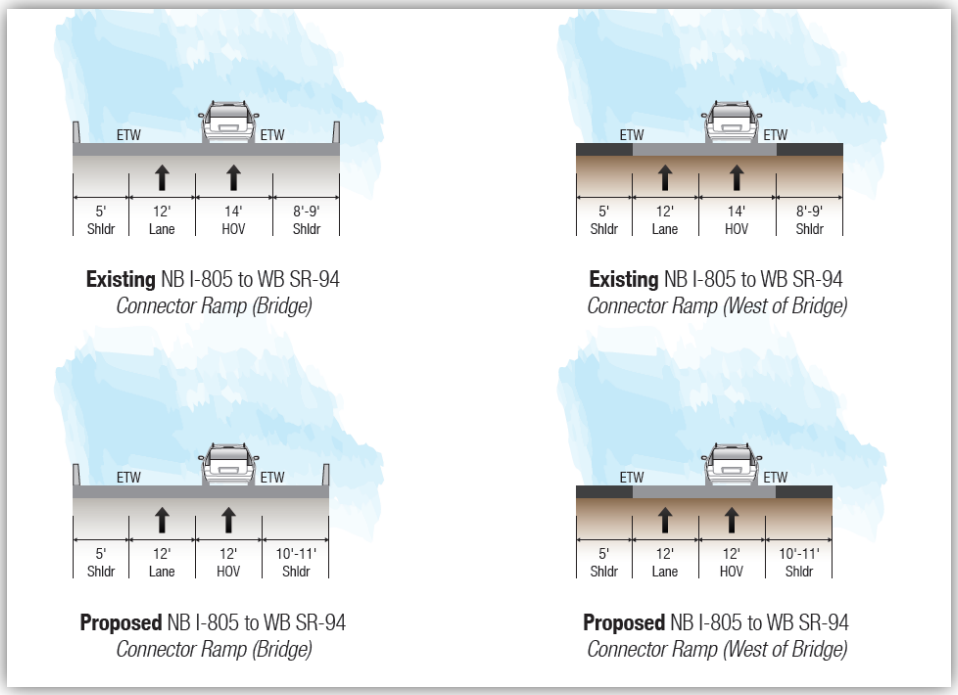

Figure 2. I-805 and SR-94 Connector Ramp Cross Sections

Proposed structural improvements SR-94

On westbound SR-94, the left shoulder will be cold-planed and overlaid with 0.15' of asphalt concrete between 25th St and 30th St to increase its structural capacity such that it can bear the loads resulting from the demonstration project.

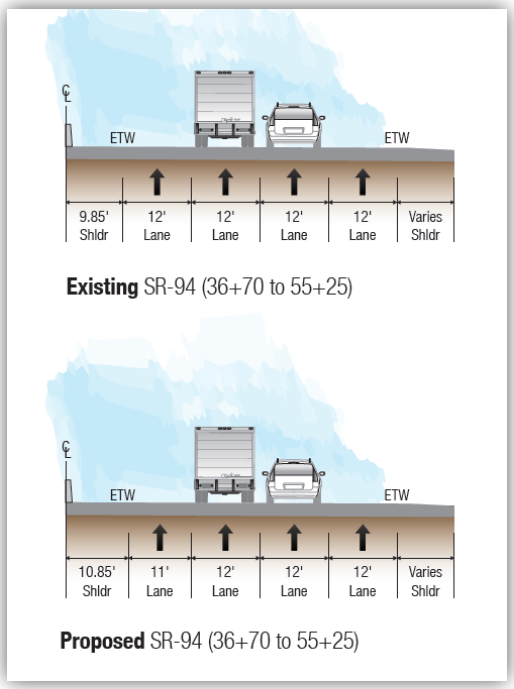

Figure 3. SR-94 Cross Section

4 OPERATIONAL NEEDS – FIELD SYSTEMS

4.1 Rationale for Project Improvements

Authorizing buses to use the shoulder on SR-94 and I-805 will allow buses to bypass congestion and maintain a high level of schedule reliability. This Bus on Shoulder system will include over five miles of ready to use shoulder lanes and several additional miles that will require minor upgrades and changes to striping and signage. During congested periods, shoulder use could improve South Bay *Rapid* passenger travel time and improve peak hour travel reliability. During the peak period, for example, improving travel time by 5 minutes means that each passenger can save over 40 hours of travel time per year by not being stuck in unusually congested conditions. Over a 3 year operating period, passengers regularly commuting on the South Bay *Rapid* service (100 passengers per trip, 12 trips per peak period) could save over 48,000 hours of cumulative travel time.

Higher travel time reliability of transit service is expected to drive higher ridership for the MTS *Rapid* service specifically in the corridor and hopefully, over the long term, throughout the region. The application of assistive technology for the bus driver will improve the safety of the ingress and egress maneuvers from the shoulder to the regular travel lanes. In particular, due to the current design of shoulder facilities, two merges will be necessary to travel on both the inside and outside shoulders during a trip. Transit signal priority at the entrance ramps will improve safety by reducing conflicts between the bus in the BOS lane and vehicles entering the freeway.

4.2 On-bus technology

Advanced driver assistance technologies (LDW, BSD, FCW, and TSP, otherwise collectively referred to as ADAS) will be installed on all buses to be operated on the South Bay *Rapid* service. The MTS AVL system will not need to be modified for this project. LDW, BSD, and FCW systems are anticipated to be procured in an off-the-shelf package that provides the sensors, electronics, and driver feedback displays and interfaces on each bus. The system is anticipated to be off-the-shelf, but procured as an aftermarket package to be installed by a system integrator. These systems will provide audio, visual, and haptic feedback to the bus driver to improve safety. The TSP will also be procured via standardized off-the-shelf components that provide a state-of-the-art platform for transit priority and future growth for additional vehicle-to-infrastructure (V2I) functionality using the vehicle-to-roadside communications platform. This will include specialized GPS hardware that can receive differential GPS signals to locate the vehicle at sub-meter accuracy for processing by the roadside unit at each ramp. The on-board vehicle-to-roadside system will broadcast the current bus location, speed, acceleration, etc. using the standard Society of Automotive Engineers (SAE) J2725 Basic Safety Message (BSM) and transmit a Signal Request Message (SRM) when in proximity to a ramp meter.

The TSP system will record high-resolution location and vehicle status data and transmit that information via Probe Vehicle Data messages to a series of roadside processors along the Rapid bus route. The roadside processor at each ramp meter will be responsible for processing the bus location and speed information and providing transit priority at the appropriate time given the current speed of the bus and distance from the conflict area. Bus drivers will not have to turn-on, turn-off, or modify any of the systems during operation.

The CHP CAD system sends incident data to the SANDAG regional data hub. When a CHP vehicle is potentially in the shoulder in the project area, the regional data hub will send an alert to the Metropolitan Transit System (MTS) Regional Transit Management System (RTMS). Transit Dispatchers may then relay this information to Rapid Bus driver via normal channels. The warning messages to the driver may either be sent via direct integration with the In-Vehicle Logic Unit (IVLU) as a canned message, or via the radio.

4.3 Ramp Metering and Traveler Information Systems

Each of the ramps along I-805 will need to be upgraded:

1. For ramps currently metered:

- A vehicle-to-roadside radio and associated processor for receiving the transit priority requests, basic safety messages, and probe vehicle data(PVD) from the bus via licensed, secure communications
- A module that will communicate the transit priority request to the ramp meter
- A module that will accept and process BSMs and PVDs from the bus for trajectory performance analysis
- Appropriate firmware version for the ramp meter so that the signal(s) on the ramp can be held in RED while the bus is approaching and until the bus has cleared the conflict area
- Ability of the ramp meter to automatically drop a transit priority request after a fixed number of seconds if the request is not withdrawn by the bus as would normally occur
- Appropriate support cabinet for the additional equipment (rack/shelf space, power, communications)
- Appropriate communications equipment to monitor, upload, and download applications and data from the TSP system.
- Provision for a geographic intersection description (GID), or more generically a high resolution "map" for locating the bus in the conflict area
- An extinguishable message sign that will indicate to motorists stopped at the on ramp that "BUS ON SHOULDER IS APPROACHING, PLEASE WAIT" (or similar message, to be determined)

2. For ramps currently NOT metered, one of the following options will be applied:

- A technology package as specified in (1), and in addition the necessary roadway and technology systems to bring the ramp up to the Caltrans District ramp metering standard
- A technology package as specified in (1), except to exclude only the necessary functions to affect the ramp meter (i.e. the extinguishable warning sign, the roadside processor and associated equipment for back-office communications)
- Static warning signs only

4.4 Data Collection and Application Validation Systems

Additional roadside units will be deployed for data collection and application validation. This can include loading of new application versions, over-the-air updates to TSP or ADAS equipment software/firmware, and off-loading of PVD messages along the route. Loading of software applications and application maintenance will take place at either the First or Last stop, when the vehicle is stationary, or at the Bus Maintenance facility. Additional roadside units will be deployed at the following locations for the interim collection of PVD messages:

- First stop (Otay Mesa Transit Center)
- Direct access ramp to I-805 (Palomar)
- Freeway exit/entrance (F/G St.)
- Last stop (India St.)

These locations will have the following equipment deployed for data collection and application validation:

- A vehicle-to-roadside radio and associated processor for receiving the basic safety messages, and probe vehicle data from the bus via licensed, secure communications
- A module to make transit priority requests
- A module that will accept and process BSMs and PVDs from the bus for trajectory performance analysis
- Appropriate support cabinet for the additional equipment (rack/shelf space, power, communications) where needed.
- Appropriate communications equipment to monitor, upload, and download applications and data from the TSP system.
- Provision for a geographic intersection description (GID), or more generically a high resolution "map" for locating the bus in the area

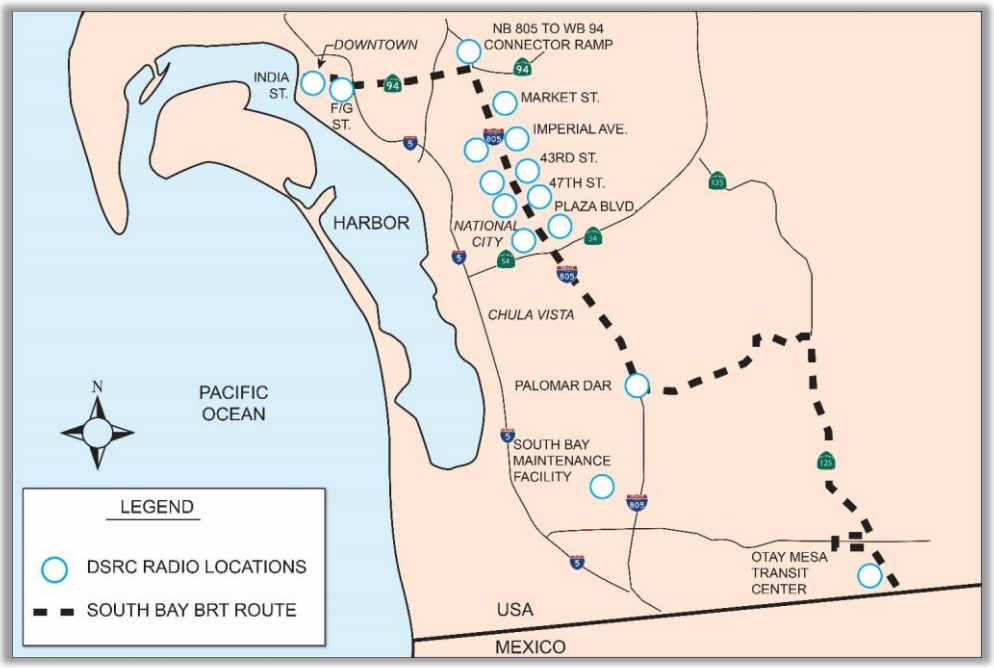

Figure 4. Map of roadside unit deployment locations along entire route

4.5 Freeway-to-freeway metering system

The connection from I-805 to SR-94 westbound is metered by Caltrans to smooth the merging flows. This location also uses the same firmware and hardware as the other ramp locations and implements the same operation policies, so the need for physical equipment upgrades is similar to the arterial entrance ramps. The key difference is the ramp meter signal poles will be supplemented by an overhead mast arm to allow for 3 lane operation.

4.6 Traveler information – CMS signs

There are no field changes required to CMS signs. Any BOS messages that might be displayed during operations would be configured and downloaded by Caltrans from the ATMS software (discussed in section 5). Changes to 511 and associated systems are discussed in section 5.

4.7 Shoulder Infrastructure

Improvements to the shoulder infrastructure are intended to mitigate the reduction in service life of the shoulder pavement resulting from the equivalent single axle loads (ESALs) of MTS *Rapid* vehicles running on the shoulder. Based on traffic index calculations performed for the existing pavement, the pavement structure on the outside shoulders of I-805 is sufficiently strong to bear the loads that will be exerted upon it throughout the life of the three-year demonstration project. However, the pavement structure on the inside shoulder of SR-94 will not be sufficient to handle these loads. Pavement mitigation treatments have been identified with the assistance of Caltrans staff.

Proposed improvements I-805

On I-805, the asphalt paved segments of the right shoulder will be overlaid with 0.1' of asphalt concrete to improve the smoothness of the ride. Additionally, this cold-plane and overlay will provide the opportunity to increase depressed area around inlets by varying the thickness of the overlay to clear the shoulder of draining water more quickly.

Proposed improvements SR-94

On SR-94, the left shoulder will be cold-planed and overlaid with 0.15' of asphalt concrete between 25th St and 30th St to increase its structural capacity such that it can bear the loads resulting from the demonstration project.

5 OPERATIONAL NEEDS – CENTRAL SYSTEMS

The intent of the Pilot project is *not* to perform all necessary "integrations" of existing and new systems with each other to enable "seamless and automated" analysis or data transfer. In the spirit of a Pilot, the intent is to implement the basic functionality first and then identify how the new systems or processes should be fully integrated with existing performance monitoring and measurement systems (e.g. PeMS, Regional Data Hub) in the future. In this project, a "dashboard" data collection and analysis system will be developed to display operational performance of the system from a variety of viewpoints (i.e. TSP events, BOS travel times, and so on).

5.1 MTS Rapid Transit Operations Software

The MTS AVL system at the transit operations center will not be modified. LDW, BSD, and FCW events will be accessible by transit operations personnel for analysis such as frequency of occurrence (in shoulder, out of shoulder), severity, and other metrics during the pilot period. GPS trajectories may be extracted from the existing bus systems at the bus maintenance facility (e.g. by WiFi upload), for comparison with the high-resolution trajectories (BSMs and PVDs) transmitted by the TSP system to the roadside processor(s). The data from the on-board TSP system will also be able to be extracted for analysis of Pilot effectiveness by offloading the PVD messages and BSMs to the roadside processors along the Rapid route. These trajectories and TSP events will be able to be transferred to the Pilot analyst(s) for evaluation and analysis.

The MTS RTMS software will receive messages related to CHP CAD events (enforcement and incident response activity of officers in the shoulder) through the SANDAG data hub. The MTS dispatchers will relay information related to CHP activity to the bus drivers operating on the shoulder through existing communication means; either through the on-board mobile data terminal or via the radio. Ramp Metering System

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The Caltrans Ramp Metering Information System (RMIS) and universal ramp metering system (URMS) will not be upgraded for the project. In the future, the following changes will be considered

- The ability of the ramp meter software user interface to indicate to an operator in real-time when the ramp meter is currently being held by a transit priority request
- The ability of the RMIS to log when and for how long the transit priority holds occur, and to generate reports on these events without undue user manipulation
- The ability of the ramp meters to be *enabled* during off-peak times and weekends, should congestion force speed drops below a threshold on the mainline lanes (and vice-versa when the speed is above the threshold)
- The ability of URMS to receive a Signal Request Message (SRM) and the associated cancellation message from the Roadside Unit, and respond with a corresponding Signal Status Message (SSM)

To address these issues a hardware-based solution will be used. The TSP processor will send the URMS the request for priority by energizing a detector input using a detector card in the detector rack in the ramp meter cabinet. When the call for TSP is released, the detector input will be de-energized, removing the call. A data logging harness will be installed in the cabinet to monitor the appropriate outputs to determine if the TSP request was serviced by the controller. When the TSP request is being served, the URMS will turn "ON" a virtual bus bypass load switch output pin. The roadside TSP processor will monitor this output to log the time-stamp of when the TSP service was started and released.

As a back-up, a video detection system will also be installed. If the wireless connected vehicles system does not activate as intended, the video detection system will place a call to the virtual bus bypass lane to enable the TSP. The video detection zone will be inside of the range of the wireless detection system so that the additional call for service will not affect the operation if the wireless system has worked correctly. The video detector will be configured to only provide the TSP operation when there is a bus in the detection zone. CHP, garbage collection, and any other vehicle type will not trigger the TSP request.

The video detection system will also be extremely valuable to the project. The camera will provide the ability of real-time remote surveillance, as well as saving time-stamped and geo-located snapshots of bus detections as they operate on the shoulder.

5.2 Freeway-to-freeway metering system

This location uses the same management software as the other ramp locations and implements the same operations policies, so the needs for central system and field changes are the same as above.

5.3 Traveler information

It will be helpful to add appropriate BOS warning messages to the CMS library and schedule the display of those messages during the BOS running time. It may be helpful to upgrade the CMS module for the ability to automatically add the CMS message to the sign display queue (WATCH FOR BUSES ON SHOULDER) if the speed drops below the operation threshold during congestion and BOS operations will be warranted. BOS messages would be shown on the signs based on their message priority (i.e. trumped by Amber alert, Silver alert, incident message, or other higher-priority information). Changes to 511 may include (1) static page(s) on the 511 website describing BOS operation, (2) real-time warning indications on the 511 map indicating when BOS operation is active in the project area. Caltrans may add daily tweets regarding BOS operation to their tweet queue during project startup, or if BOS is operational during off-peak times per the discretion of Caltrans. Other traveler information products will be developed in the public awareness campaign, addressed separately.

5.4 Back-office TSP Prototype Management Software

In the USDOT RESCUME concept of operations, a variety of status information from transportation management systems are proposed to be transmitted to Public Safety systems. In the Bus on Shoulder operation of this Pilot project, when the Bus is determined to be operating on the shoulder, via its first contact with a roadside unit on I-805, the roadside processor will relay this information to a new central system process that make this information available through an API. At a future time this

information may be relayed to CHP CAD system or others via a prototype message based on CAD interface standards developed for RESCUME.

The prototype TSP management software will collect the TSP request, cancellation, and service data from the field processors and organize and display the data for use by the SANDAG analysts. The back-office TSP Management System will be responsible for collecting, storing, summarizing, and displaying BOS PVD Messages, BSMs, and SRMs. The system will also display the operational status of all field radios and field processors.

5.5 CHP CAD system

In the USDOT RESCUME concept of operations, a variety of status information from transportation management systems are proposed to be transmitted to Public Safety systems. In the Bus on Shoulder operation of this Pilot project, when the Bus is determined to be operating on the shoulder, via its first contact with a roadside unit on I-805, the roadside processor will relay this information to a new central system process which will then make available via API a prototype message based on CAD interface standards developed for RESCUME. An interface may be added at a future time to share BOS status updates directly with CHP CAD or through alternative means, such as a secure web page.

5.6 Data sharing

The SANDAG data hub will be responsible for sharing CHP activity with MTS RTMS. When the CHP is in the shoulder managing an incident in the BOS operating area, a geo-fence function will detect this in the SANDAG data hub system. The data hub will send a message to the MTS RTMS system. The MTS dispatcher will then have the option to warn the bus driver using traditional means including the radio or the on-board mobile data terminal.

The following elements will be transferred from their respective systems (via to-be-specified technical means) to the Pilot system analyst(s):

- GPS tracks from the existing AVL system on the bus
- FCW, BSD, and LDW events
- TSP signal status message and signal priority service requests
- Probe Vehicle Data messages and trajectories of BSMs
- Probe Management Message in effect for that freeway segment
- Warning messages of Bus on Shoulder from the TSP central system to the MTS RTMS system
- Video images of BOS operations from the video detection system
- Other operational data as needed for BOS effectiveness assessment

6 SUPPORT ENVIRONMENT

6.1 Data configuration

On-bus, roadside, and RMIS/ATMS systems require data configuration and setup.

On-bus Systems
FCW, LDW, and BSD systems have parameters than can be set and tuned by the integrator during installation. The vehicle-to-roadside communications system has several parameters including IPv4/IPv6 addresses and channel assignments. The TSP on the bus will broadcast a TSP request and basic safety message (BSM) using the SAE defined 'Provider Service Identifier' (PSID) for 'private testing'. The on-board processor will be configured to broadcast these messages on startup.

Roadside systems
The roadside communications system also has similar parameters to the on-board vehicle communication system. The Geometric Information Description (GID, otherwise known as a "map") will be configured for each ramp meter. The roadside processor may have several (to-be-determined) parameters to determine the timing of TSP requests and cancellations to the ramp meter based on vehicle location and speed. The roadside units can be configured to change the parameters for collection, storage, and transmission of PVD messages from the Rapid buses equipped with the TSP equipment. This includes the frequency of data points and the content of each snapshot. In addition to standard information regarding velocity, heading, acceleration, and precise location, snapshots could include data such as wiper status, headlights and auxiliary flashers on/off, and additional data as defined in SAE J2735.

The ramp meter will be configured to hold the approach lanes in red for a configurable number of seconds until the bus exits the conflict area. The ramp meter will be configured to have a "virtual bus bypass lane" such that when a detection call is placed on the bus arrival detector in that virtual lane, the other lanes are held in red until the call is placed from the virtual bus departure detector. The ramp meter will trigger the message sign ("BUS ON SHOULDER, PLEASE WAIT") when the virtual bus bypass lane is in virtual green. When the virtual bus bypass lane is red, the message sign will be turned off. All other ramp meter parameters will be configured normally.

A video detection camera system will be installed at each ramp meter to provide a back-up operation to the wireless-based TSP request system. The video detection will be placed inside of the range of the wireless connected vehicle detection range. The placement of the video detection zone will be configurable.

Back office systems
Operators at the Caltrans TMC will be able to configure any new parameters in URMS. The operator will be able to add, modify, and delete the new parameters (along with all other existing parameters) and upload and download those parameters to the ramp meter. The real-time status of the TSP requests (via the call to and release from the virtual bus bypass detectors) will be implemented in the TSP monitoring system. Input-output monitoring harnesses will be installed in each ramp metering

cabinet to obtain time-stamped ON and OFF events for all inputs and outputs from the controller. This harness is principally to detect the virtual bus bypass lane output which will determine that the ramp meter has serviced the call, and terminated the TSP status when the request for TSP is released. These events will be time-stamped and logged by each RSE.

All events will be able to be logged for evaluation by the Pilot analyst(s) using the back-office system.

In the Caltrans District 11 ATMS system, the new BOS messages ("WATCH FOR BUS ON SHOULDER") may be added to the CMS message library and the message display schedule. The operator at the Caltrans TMC may configure the display priority of the new BOS messages. All other existing sign configuration parameters will apply to the BOS messages.

Roadside radios and field processors will be able to be remotely configured for their relevant parameters. At the pilot stage of deployment, it is expected that some of these features and functionality may be at a prototype stage. This includes the ability of the back-office system to automatically send a notification message to the MTS RTMS system when CHP are operating on the shoulder. The MTS RTMS system will need to be modified to accept the message and display the message for the Dispatch operator. Based on feasibility analysis of this technical approach, it may be necessary to provide the MTS dispatchers BOS status updates through alternative means, such as a secure web page.

6.2 Alerts

The following categories of Alerts will be helpful to obtain from appropriate systems through appropriate means:

1. Loss of communications from a central management software to a field device
2. Software application errors and failures
3. Hardware errors and failures
4. Bus is operating on shoulder (MTS RTMS alert message was successfully sent via API from the BOS back-office system to appropriate systems)
5. Bus has successfully sent and received priority at a ramp
6. Bus has successfully sent request for priority at a ramp but priority was not provided
7. Operator ADAS alerts for FCW, LDW, or BSW have been enabled
8. CHP is operating on the shoulder (inferred via CHP CAD incident locations) and message successfully sent to MTS RTMS system
9. Video detection of bus on approach in the shoulder

6.3 Performance Monitoring

The following data may be used for computation of performance metrics:

1. PeMS data on freeway conditions during the evaluation period

2. GPS traces on MTS *Rapid* buses in the I-805 corridor, from the MTS AVL system
3. TSP activations at ramp meters
4. Probe Vehicle Data messages and trajectories from the TSP system
5. Notifications of Bus on Shoulder from the back-office TSP management software to the MTS RTMS system (or secure web page showing BOS status per results of future feasibility analysis)
6. Notifications of CHP on Shoulder (inferred from CHP CAD incident locations) from the regional data hub to the MTS RTMS
7. Activations of FCW, BSD, and LDW warnings
8. Activations of ramp queue detectors on metered ramps
9. Alert logs for service outages
10. Maintenance logs
11. Lane closures
12. Shoulder events and incidents
13. Crashes
14. Transit analytics logs

6.4 Support Personnel and Support Procedures

It is anticipated that a single system integration team will be contracted to provide the technology solutions for this Pilot project. A separate construction contractor will be used to build the physical infrastructure such as conduit, cabinet bases, and power connections; upgrade shoulder pavements where necessary, and install poles and mounts. The technology system Integrator team personnel will be responsible for repair and maintenance of on-board equipment, roadside equipment, and back office systems during the Pilot project. The system integrator will be informed by Caltrans or MTS personnel, as appropriate, to respond to a trouble call. Trouble calls will be logged for performance reporting. Designated support personnel will respond per the maintenance agreement, typically with different urgencies depending on the level of issue (e.g. within 4 hours for critical failures, within 1 day for nuisances, etc.). Vendors/System Integrators will replace or repair equipment and provide software patches within the terms of the maintenance agreement. Caltrans will be responsible for support and changes to URMS and back-office management systems for monitoring ramp meters and CMS. MTS will be responsible for modifications to the MTS RTMS system to accept the notification message from the TSP prototype software, if feasible. If the RTMS system modifications are not feasible, secure web page showing BOS status will be developed by the system integrator and made available to both CHP & MTS Dispatchers.

6.5 Transportation System Maintenance & Operations

System Integrators and vendors will provide periodic “check-ups” of system equipment and software on a periodic basis during the project to ensure that the project is operating smoothly. At minimum, system integrator teams, SANDAG, Caltrans, and MTS will meet on a weekly basis to review operations and make necessary adjustments during the initial deployment and testing phase and initial revenue operations period. Check-ups will include inspection of all on-board equipment, inspection of all field equipment, inspection of all central system software and systems, review of databases and any clean-up of temp

files, unnecessary backups, and the like. Check-ups will coordinate with SANDAG analysts to review performance reports and operational reports from MTS, Caltrans, and SANDAG staff. Weekly meetings may be moved to less frequent recurrence after the initial start-up phases.

7 USER-ORIENTED OPERATIONAL SCENARIOS

Along I-805, MTS transit buses will utilize the outside (i.e. the right-hand-side) shoulder in both the northbound and southbound directions between SR-54 and SR-94. Where existing auxiliary lanes are available, buses may utilize the auxiliary lane instead of the outside shoulder. On the northbound I-805 to westbound SR-94 connector, buses will utilize a restriped outside shoulder onto SR-94. Along westbound SR-94, starting at 30th Street, buses would travel along the inside (i.e. the left-hand-side) shoulder into downtown San Diego. On eastbound SR-94 to southbound I-805, the buses would utilize the outside shoulder onto southbound I-805.

MTS transit buses will operate within the appropriate shoulders during periods of heavy traffic congestion when the general-purpose lanes are operating at less than 35 miles per hour. When buses utilize the freeway shoulder, they will only be allowed to travel up to 15 mph faster than the adjacent speed of traffic in the general-purpose lanes, and not to exceed 35 mph. Based on existing traffic conditions, bus on shoulder operation will likely occur on a daily basis M-F between 6:00 AM to 9:00 AM (northbound) and 3:00 PM to 6:00 PM (southbound). Four to six buses per hour are anticipated to operate BOS during the peak periods.

7.1 Northbound South Bay Rapid Buses

The South Bay *Rapid* corridor extends between the U.S.-Mexico border and downtown San Diego. The buses are dispatched from the bus Maintenance Facility. A TSP roadside unit is installed at the bus barn to validate operations before leaving on the route and to configure the Probe Vehicle Data (PVD) messages for the initial trip segment. The route begins at the US-Mexico border where the buses pass an additional TSP roadside unit for collecting bus PVD messages, from which point buses will then travel north through the City of Chula Vista before entering the I-805 freeway at East Palomar St. The buses will enter the freeway via a newly constructed Direct Access Ramp (DAR) that provides direct access to the HOV lanes in the median of I-805. At the direct access ramp, the buses pass a TSP roadside unit where the PVD messages are offloaded from the bus to the roadside unit and the PDM parameters for the freeway segment data capture may be modified. The South Bay *Rapid* buses will travel in the HOV lanes until they reach an intermediate HOV ingress/egress area just north of SR-54. At the intermediate ingress/egress area, the buses will begin merging to the right, out of the I-805 HOV lanes and into the general-purpose lanes, a maneuver that will be assisted by blind spot detection and forward collision warning systems.

The Bus on Shoulder Project begins just north of SR-54. Operational policy dictates that the buses may utilize the shoulder when speeds in the general-purpose lanes fall below 35 mph. Buses may operate in the shoulder at a speed of up to 15 miles per hour faster than the speed of the adjacent general-purpose lanes, not to exceed 35 mph. These speed restrictions are designed to minimize the potential for serious crashes if a vehicle unexpectedly enters the shoulder. New signage and striping will be implemented that will alert drivers to the BOS operations. CMS signs in the corridor may also display warning messages to drivers that Buses are operating on the Shoulder. When the Bus is on the shoulder, the TSP system records the event in the back-office system. These data will be relayed through an API to additional systems such as MTS RTMS, regional data hub, and CHP CAD at a time after the completion of the pilot.

While driving on the shoulder, a lane departure warning system will operate passively and assist the bus drivers in keeping a safe operating position. A transit signal priority (TSP) system will also be implemented to control ramp signals. The TSP system will hold approaching vehicles at the ramp meter as the bus passes the potential conflict point between the outside freeway shoulder and the ramp entrance. An active warning message will be displayed for the drivers on the ramp indicating in real-time when the bus is on the shoulder approaching the conflict area. As the bus passes each ramp, the basic safety messages and PVD messages are sent to the roadside unit for performance monitoring.

If there are any obstructions or incidents on the shoulder in the path of the bus, the driver will merge into the right-most general-purpose lane until it is past the obstruction. Once past the obstruction, the bus driver will have the option to merge back into the shoulder when operational conditions permit. In some segments of the I-805 freeway there are auxiliary lanes between entrance ramps and off-ramps. If an auxiliary lane is present, the bus may use the auxiliary lane instead of the shoulder. This will minimize steering maneuvers that provide limited or in most cases probably no appreciable speed performance advantage.

As the northbound South Bay *Rapid* bus transitions from northbound I-805 to westbound SR-94, buses will utilize a restriped outside shoulder onto SR-94, bypassing the ramp meter. Once on westbound SR-94, the South Bay *Rapid* buses will merge to the left-most general-purpose lane until the inside shoulder of SR-94 becomes available, west of SR-15. As the bus transitions to SR-94, it passes the final roadside unit on the freeway portion of the route at which the PVD messages are exchanged and the reporting parameters for PVD messages may be modified a final time for the remaining surface-street portion of the Rapid route. At this point, the TSP system on-board the bus communicates to the final freeway roadside unit that the bus is no longer operating on the shoulder. At the last stop on the route, the PVD messages are exchanged with a final roadside unit and the reporting of PVD is suspended until the bus begins the return Southbound route after turning around.

7.2 Southbound South Bay Rapid Buses

The South Bay *Rapid* will return passengers from downtown San Diego along the same route. Buses will enter the eastbound SR-94 freeway from the G Street entrance ramp. Buses will travel in the general-purpose lanes from the G Street entrance ramp to the connector ramp that connects eastbound SR-94 to southbound I-805. Under the freeway operating conditions described above relating to the speeds in the general-purpose lanes, buses will be able to utilize the outside shoulder on SR-94, as well as the connector ramp onto southbound I-805. South Bay *Rapid* buses will then utilize the outside shoulder for travel on southbound I-805. Where auxiliary lanes exist on southbound I-805, the buses may move into the auxiliary lane, rather than remaining on the shoulder. The same operational policies of maximum 35 mph speed on the shoulder and the 15 mph speed differential will be in effect for southbound South Bay *Rapid* buses as for the northbound buses. Ramp entrances in the southbound direction are not metered, so there is no TSP functionality. However, the TSP roadside equipment is installed to enable the warning message sign, offload the PVD messages, and send the notification message to the TSP back-office system that the bus is operating on the shoulder. The LDW, BSD, and FCW systems are enabled as in northbound travel.

As the southbound buses approach the intermediate ingress/egress point on southbound I-805 just north of SR-54, they will begin merging left to enter the southbound I-805 HOV lanes, again using the

blind spot detection and forward collision warning systems. From that point on, the southbound South Bay *Rapid* buses will travel in the southbound I-805 HOV lanes to the East Palomar Street Direct Access Ramp (DAR). The South Bay *Rapid* buses will then exit southbound I-805 at the East Palomar Street DAR and continue routing through the City of Chula Vista, and on to the Otay Mesa border crossing area. As the bus transitions to East Palomar Street it passes the final roadside unit on the freeway portion of the route at the DAR which the PVD messages are exchanged and the reporting parameters for PVD messages may be modified a final time for the remaining surface-street portion of the Rapid route. At this point, the TSP system on-board the bus communicates to the final freeway roadside unit that the bus is no longer operating on the shoulder. At the last stop on the route at the US-Mexico Border, the PVD messages are exchanged with a final roadside unit and the reporting of PVD is suspended until the bus begins the return Northbound route after turning around.

7.3 System Users

Table 2 provides a listing of the anticipated users of the BOS system(s), as well as an overview of their anticipated use of the system(s).

Table 2. User Types and Anticipated Uses

User	Anticipated Use of the System
Passenger	• Revenue passenger
Bus Operator	• Operates the transit bus in revenue service in accordance with agency policies and procedures, and established safe operations practices • Performs a basic bus safety inspection at the beginning of each shift • Will make final "on the fly" decisions on appropriate use of the shoulder based on agency training, operational parameters (prevailing speeds and weather), and route experience • Monitors and responds as appropriate to alerts from the proposed blind spot detection system • Monitors and responds as appropriate to alerts from the proposed lane departure warning system • Monitors and responds as appropriate to alerts from the proposed forward collision warning system • Conveys certain operational events that occur along the route, as it is safe to do so: incidents or shoulder blocking events, any other issue or anomalous operating event. • Reports lessons learned and makes suggestions to improve bus on shoulder operations and safety • Assists with training of new bus operators that take on bus on shoulder driving assignments • Reports any issues and/or anomalous events with the assistive technologies deployed on the bus to support the bus on shoulder operations (lane departure warning system, blind spot detection system, etc.)

User	Anticipated Use of the System
MTS Dispatcher	• Performs general bus dispatch and location monitoring duties, in accordance with agency policies and procedures, and established safe operations practices • Receives and monitors reports from bus operators on status of bus on shoulder operations • Responds to, and further reports as appropriate, any issues or anomalous events reported by bus operators and operations supervisors • Provides operational or policy direction to bus operators as appropriate, and when necessary • Receives and monitors vehicle condition reports from bus operators and provides information to maintenance personnel, as appropriate • Relays information to bus drivers regarding CHP officers in the shoulder via radio
Operations Supervisor	• Acts as a first line field supervisor for bus operators • Works in conjunction with Dispatchers to monitor bus on shoulder operations • Works in conjunction with Dispatchers to respond to issues and anomalous events • Provides operational or policy direction to bus operators as appropriate, and when necessary
California Highway Patrol Officer	• Responds to incidents on state highways • Generally provides first response to any other type of emergency or law enforcement action on state highways • Performs traffic enforcement activities on state highways • Provides assistance to disabled vehicles, including MTS buses
Caltrans Maintenance Personnel	• Performs routine maintenance on state highways • Responds to major incidents on state highways • Performs sweeps of shoulder within project limits to remove debris • Performs traffic operations and safety analyses on state highways • Provide recommendations for safe highway operations • Performs safety inspections on physical facilities (roadways, bridges, and drainage facilities) on state highways • Responds to calls for assistance to clear debris from the roadway on state highways

User	Anticipated Use of the System
MTS Maintenance Personnel	• Performs safety inspections on MTS buses • Performs routine maintenance on MTS buses and all installed ancillary equipment • Performs troubleshooting on all mechanical systems reported to be malfunctioning, and/or detected to be operating outside of specified tolerances • Responds to major incidents involving MTS transit vehicles
Freeway Service Patrol Personnel	• Provides assistance to disabled motorists, including MTS buses, on state highways • Provides assistance to CHP and Caltrans personnel, as directed, in response to incidents and other major events on state highways
Caltrans ATMS Operators	• Configure and monitor ramp metering operation • Configure and monitor CMS messaging and displays • Monitor RMIS/URMS operation for TSP and report anomalies
Caltrans URMS developer	• Potential future role to modify URMS for TSP operations resulting from the findings of the Pilot project
Pilot Analysts	• Obtain TSP reports and related operational data for system assessment • Prepares responses to Federal Transit Administration on Pilot project performance
System Integrators/Vendors	• Configures, tests, and maintains on-board equipment • Configures, tests, and maintains roadside equipment • Configures, tests, and maintains back office software and systems

7.4 OPERATIONAL SCENARIOS

Each scenario describes a sequence of events, activities carried out by the user, the system, and the environment. It specifies what triggers the sequence, who or what performs each step, when communications occur and to whom or what, and what information is being communicated.

The scenarios include

- Normal operations,
- Incidents,
- Planned construction,
- Training
- Maintenance

7.5 Scenario – Typical Daily Operations

Bus Operator

Michelle is an experienced MTS Bus Operator, with an excellent safety record, driving a bus on the new South Bay *Rapid* route. As Michelle drives her South Bay *Rapid* bus on a northbound run, she leaves the Otay Mesa Border Crossing area, enters SR-125, and exits SR-125 in the City of Chula Vista. The South Bay *Rapid* route continues through the City of Chula Vista on surface streets, heading towards the northern terminus point in Downtown San Diego. Michelle enters the I-805 freeway at East Palomar St, using the recently opened Direct Access Ramp (DAR) that provides direct access to the I-805 Express Lanes in the median of I-805. The DAR eliminates the need to merge from the right-hand lanes to the Express Lanes on the left-hand side of the northbound traveled way. Michelle drives her South Bay *Rapid* bus in the I-805 Express Lanes until she reaches an intermediate Express Lanes ingress/egress area just north of SR-54.

At the intermediate ingress/egress area, Michelle needs to exit the northbound Express Lanes at this location because this is the last ingress/egress area that will give her an opportunity to exit the Express Lanes and safely merge to the right to transition to SR-94. Michelle begins merging her bus to the right, out of the I-805 Express Lanes and into the general-purpose lanes. The blind spot detection system assists her with the merge movement out of the Express Lanes by displaying a visual indication, and audio cue, and providing haptic feedback. The blind spot detection system is always passively detecting vehicles in the blind spot but when the turn signal is activated the alarms become active. The forward collision warning system is continuously detecting the potential for the bus to collide with a vehicle or obstruction ahead of the bus by calculating the time-to-collision. When the time-to-collision is below a threshold, the forward collision warning system will display a visual indication, provide an audio cue, and provide haptic feedback to Michelle. The lane departure system helps Michelle stay within her lane when the turn signal is not active by providing audio, visual, and haptic feedback if she strays across one of the lane lines.

Michelle successfully and safely makes the transition to the right-most travel lane and drives in that lane for approximately 1 mile before traffic in the general-purpose lanes begins to slow. The slowing traffic quickly becomes “stop and go” conditions. Michelle determines that, according to the bus on

shoulder operations policies, she learned in her training classes, she is eligible to enter the shoulder to bypass congested driving conditions. Michelle determines that the approximate speed of traffic in the general-purpose lanes is approximately 10 MPH, which means that the fastest she can operate her bus on the shoulder is 25 MPH.

The lane departure warning system helps Michelle maintain a safe operating position in the shoulder lane. Michelle typically only receives a couple of warnings that she is not in the optimal position on the shoulder on each run. The LDW system may trigger unintentionally when Michelle crosses ramp designations in the conflict area.

Michelle has never had the forward collision warning system activate in revenue operations, only in her training activities. The typically low operating vehicle speeds, and the relatively straight sight lines of the shoulder operating areas have thus far provided Michelle the ability to avoid activation of the forward collision warning system.

The Transit Signal Priority (TSP) communicates with the ramp meter signals at each entrance ramp to hold vehicles entering the freeway at the ramp metering stop bar when the bus is approaching the entrance ramp merge point. The signals are held in red until the request is cancelled when the bus exits the conflict area, or after a configurable number of seconds of continuous hold. A message sign(s) is/are illuminated proximate to the ramp meter, indicating to drivers that the bus is approaching on the shoulder. Briefly stopping those vehicles creates a safe gap in traffic entering the freeway so the bus can safely pass through the entrance ramp merge point without conflict. The sign is turned off after the bus exits the conflict area. Michelle is still very cautious and slows down slightly at the entrance ramp merge areas because she knows from experience that some drivers may not pay heed to the red ramp metering lights. After the bus exits the merge area of the ramp, the message is removed on the display for the drivers and the ramp meter returns to normal operation.

As Michelle's northbound South Bay *Rapid* bus approaches the connector ramp from northbound I-805 to westbound SR-94, she is typically in the shoulder to bypass slow traffic on the connector ramp. She keeps the bus in the shoulder lane on the connector ramp, bypassing the freeway to freeway connector ramp meter and enters the shoulder on westbound SR-94. The same transit priority request message is sent to the freeway to freeway connector meter and the main travel lanes are held red until the bus exits the conflict area. The extinguishable message is illuminated warning drivers that the bus is approaching on the shoulder.

Once on westbound SR-94, Michelle immediately begins merging her bus into the left-hand lanes to access the inside shoulder of SR-94. The blind spot detection and forward collision warning systems provide assistance in ensuring that she is safely merging the bus to the left, into the left-hand lanes. As Michelle passes 30th Street, she merges her bus into the inside shoulder of SR-94 until she passes 25th Street, where she diverges from the shoulder into the left-hand lane of SR-94 for the remainder of her travel on SR-94, into Downtown San Diego. The appropriate in-vehicle technology (lane departure warning, forward collision warning, blind spot detection) is still engaged while traveling along the inside shoulder of SR-94. Michelle exits SR-94 on the Balboa Park/Downtown exit, where she enters the Downtown San Diego area on F Street.

Dispatcher

Ricardo is an MTS Bus Dispatcher. The bus dispatcher assigns each driver to a block of work for the day which includes the MTS *Rapid* Service. MTS utilizes a global positioning system (GPS) based automated vehicle location (AVL) system for real-time tracking of fixed route buses. The system is monitored by MTS dispatchers, who are available to provide assistance for operational issues encountered by the bus operators in the field. The dispatchers also use the AVL system to provide first line emergency response for incidents and other emergencies that impact MTS buses, drivers, and passengers. The system also archives data that is used for future planning and operations analysis.

MTS dispatchers have other means that they utilize to monitor traffic and incidents throughout the greater San Diego metropolitan area. The system is called the Integrated Corridor Management System (ICMS). ICMS is an integrated, multi-agency, multimodal transportation management system, owned and operated by SANDAG, in partnership with Caltrans, CHP, MTS, and several other local agencies in the region. ICMS is primarily associated with the I-15 Integrated Corridor Management project, which is an effort to integrate and manage multiple transportation modes and systems to be operated and managed as a unified network. A wide variety of transportation management information is available to Ricardo and the other MTS Dispatchers on ICMS, including real time bus location information from the MTS AVL system.

The primary information from ICMS that is utilized by the MTS Dispatchers to help manage MTS operations is congestion and incident information. MTS Dispatchers can view MTS bus locations, as well as traffic conditions (primarily on the freeways) and active incidents reported to and/or managed by CHP, that may impact MTS transit vehicle operations. Because of the multitude of minute to minute duties performed by the MTS Dispatchers throughout the day, it is not possible for the Dispatchers to catch every incident, and to inform bus operators about every incident that may impact transit operations. However, ICMS has proven to be a useful tool, and Ricardo uses it to the best of his ability. Several times throughout the day, Ricardo and the other Dispatchers view the ICMS map and look at the freeways on which MTS drive for some portion of their route. Now, with the bus on shoulder operations fully implemented, Ricardo looks a little closer to see if there are any incidents that may include vehicles or emergency response activities on the shoulder on I-805. Since ICMS shows incidents and MTS bus locations, it is easier to anticipate if or when congestion or an incident is impacting (or will impact) MTS operations. When CHP is operating on the shoulder, the status is shown on the MTS RTMS or a secure web page and Ricardo informs the bus drivers via radio or mobile data terminal text message.

Passenger

Robert lives in the Otay Ranch area of Chula Vista, and works in Downtown San Diego. Robert was looking for an alternative to driving into downtown by himself every day. On a few occasions, he tried taking a local MTS bus west through Chula Vista, and transferring to the Trolley Blue Line. However, he thought it was a little inconvenient for him, so he hasn't made it a regular method of commuting to work. Then he heard about the start-up of the MTS South Bay *Rapid* service from the Otay Mesa border crossing area, through eastern Chula Vista, and into Downtown San Diego. When he investigated, Robert found that he could park his car at the Park & Ride lot at the Otay Ranch *Rapid* Station, and that the end of the route in Downtown San Diego was just a couple blocks from his office. He also liked that the *Rapid* service had far fewer stops to make along the route, which sounded a lot more convenient than the local bus that made many stops along the way.

The first time Robert took the South Bay *Rapid* bus to work, he liked the new, clean, modern station and buses. He also liked that there was secure parking for him to park his car for the day while he was at work. And, he was impressed with the bus arrival signs that indicate the predicted arrival time for the *Rapid* bus as it makes its way from the Otay Mesa border crossing area to the Otay Ranch Town Center Rapid Station. He found it to be pretty reliable and could relax a little while waiting on the platform for the bus to arrive, rather than wondering if it was on its way, when it would get there, and if he would be to work on time.

When Robert did his research on South Bay *Rapid*, he read in an online news article that the South Bay *Rapid* buses would be driving on some portions of the freeway shoulder on I-805 and SR-94, to bypass traffic congestion in the regular lanes. It made him a little nervous when he first read about it, but he assumed it would be safe, and he liked the idea of the travel time advantage the bus would gain, over the regular traffic lanes. He's driven that route many times and knows that congestion on I-805 and SR-94 can be rather unpleasant most weekdays. After riding on the bus on the shoulder a couple times, Robert decided that the bus driving on the shoulder is great. He thinks the bus operators drive with great skill, and make smooth transitions onto and off the shoulder very smooth.

Operations Supervisor

Amy is an MTS Bus Operations Supervisor. When the bus on shoulder operations first began, she scheduled regular conversations with the bus operators to make sure that she had a handle on any questions, comments, or concerns from the bus operators. She wanted to facilitate that feedback to management and make sure that concerns, if any, are being addressed. As the bus on shoulder operations mature for MTS, she finds it less pressing to meet with the bus operators as frequently as when the service was brand new. But she makes sure to engage any newly assigned drivers to make sure they have the same opportunity to provide feedback. This is also a good opportunity to provide lessons learned for the bus operators that are new to the shoulder operations.

On a day to day basis, Amy has many duties, both in the office and in the field. She regularly reviews safety and performance reports, and coordinates any issues or concerns with the MTS Dispatchers, the drivers she supervises, and with management. She regularly meets with the South Bay *Rapid* drivers to make sure she is on top of any issues or concerns that may arise, but she is only periodically involved in any real time operational decision making. When in the field, and as time allows, she will drive the South Bay *Rapid* route to make sure she is aware of any changes in the characteristics of the route, and the general condition of the MTS field equipment and amenities.

Caltrans Maintenance

Tammy is a Caltrans maintenance supervisor. As a maintenance supervisor, Tammy has her crews perform shoulder sweeps along I-805. With BOS operations, her crews now sweep the shoulders more often than normally to maintain normal operations with shoulders free of debris.

MTS Maintenance

No role in normal operations.

California Highway Patrol

CHP may encounter buses on the shoulder when using the shoulder to progress towards a downstream incident during extreme congested conditions. The bus will be obligated to move back into the regular

travel lanes when notified via lights and sirens allowing the CHP vehicle to continue on the shoulder to the emergency.

Freeway Service Patrol

May be contracted to support Caltrans maintenance in sweeping shoulders of debris that could impact BOS operations.

Caltrans TMC Operators

Kwame is TMC Operator at the Caltrans District 11 TMC. Kwame monitors RMIS for ramp metering. Jose monitors ATMS for freeway operations. Jose monitors ATMS for incidents, CMS messages, as well as management of other devices.

On a daily basis, during the introduction of BOS operations on I-805, Jose may post messages on a scheduled basis on the I-805 CMS that inform drivers to watch for BOS. The message could play several times per day in the AM peak periods. During off-peak incidents, when the CMS is informing drivers of downstream congestion, Kwame adds additional message to the incident information warning drivers to watch for BOS.

Pilot Analyst(s)

On a weekly basis, Susan evaluates AVL, TSP, LDW, BSD, and FCW events and PVD trajectories data along the BOS route. Susan evaluates the system effectiveness in a variety of ways, including by Freeway Segment, Route Number, Run Number, Time of Day, or other user defined scenarios in the back-office prototype data collection and analysis system developed for this project.

System Integrator/Vendor

Once the system is installed, tested, and certified by SANDAG, MTS, and Caltrans to be operational, the system integrator is not involved in day-to-day operations. The system integrator responds to trouble calls and repairs or replaces equipment or software as necessary.

7.6 Scenario – Incidents That Directly Impact Shoulder Operations

Bus Operator

Michelle learned in the classroom training that obstacles on the shoulder, particularly disabled vehicles and law enforcement vehicles performing enforcement activities, would pose a challenge to the effectiveness of the shoulder running operations. She and the other bus operators were instructed to beware of such obstacles, and when operating on the shoulder, to be prepared to leave the shoulder area in the event they encounter any type of obstacle on the shoulder. The MTS Dispatchers try to give forewarning of obstacles on the shoulder at the beginning of the shift or at any stop**.** It will likely be more common that Michelle will encounter blockages or issues with shoulder running and report these issues to the dispatcher at her next stop.

Michelle was also instructed that, depending on the location of the obstacle, that the decision to re-enter the shoulder after passing an obstacle is largely left to the judgement of the bus operator. If in the bus operator's opinion, there is significant advantage to be gained by re-entering the shoulder, that the bus operator should do so at the earliest safe opportunity. However, if the obstacle is located close enough to a place where the bus is required to leave the shoulder area anyway, and that it would require multiple lane changes out of and back into the general-purpose lanes over a relatively short distance, and the advantage to be gained is likely to be off-set by the multiple lane changes, then the bus operator should just remain in the general-purpose lane until the next opportunity to re-enter the shoulder is reached.

Twice last week Michelle encountered obstacles in the shoulder that required her to move out of the shoulder into the general-purpose lanes. In the first instance, she encountered two vehicles that had been involved in a relatively minor accident. The drivers appeared to be out of their vehicles exchanging information. Michelle slowed and turned on her left turn signal indicator, to alert drivers in the adjacent general-purpose lane her intention to leave the shoulder area. She had to wait for a few cars to pass the bus, and another driver to slow down to allow her to merge the bus back into the adjacent general-purpose lane. The blind spot detection system did not detect any vehicles in her blind spot, so she moved into the adjacent lane. Once in the general-purpose lanes, she quickly determined that there was a fairly significant advantage to be gained by re-entering the shoulder, because the next forced exit from the shoulder was more than a half mile ahead. So as soon as she was safely past the vehicles in the shoulder, she moved back onto the shoulder. She passed many vehicles in the adjacent general-purpose lane and felt like she had gained the advantage of using the shoulder.

In the other instance last week where Michelle encountered an obstacle on the shoulder, the outcome was a little different. At another segment of the freeway, Michelle encountered a CHP officer on the shoulder, engaged with another motorist. She merged the bus into the adjacent general-purpose lane to go around the CHP vehicle and the other motorist. Once she re-entered the adjacent general-purpose lane, she determined that less than a quarter mile ahead there is a point at which the buses must leave the shoulder area and re-enter the general-purpose lanes. She determined that the advantage of diverging back onto the shoulder, and then re-entering the adjacent general-purpose lane did not outweigh the effort required to perform multiple lane changes in a relatively short distance. So she retained her position in the general-purpose lanes, and continued on until there was another appropriate opportunity to diverge onto the shoulder, at which time she did so.

In areas where there is an auxiliary lane, Michelle has been trained to bring the bus off the shoulder and into the auxiliary lane until the auxiliary lane terminates, at which point, if Michelle deems it advantageous, she diverges the bus from the auxiliary lane back onto the shoulder. With appropriate striping, in most areas this does not require much steering on Michelle's part as the shoulder is aligned with the auxiliary lane.

Dispatcher

MTS Dispatchers can view MTS bus locations, as well as traffic conditions (primarily on the freeways) and active incidents reported to and/or managed by CHP, that may impact MTS transit vehicle operations. However, because of the multitude of minute to minute duties performed by the MTS Dispatchers throughout the day, it is not possible for the Dispatchers to catch every incident, and to inform bus operators about every incident that may impact transit operations. Earlier today, Ricardo noticed an incident on I-805 that appeared on ICMS. He was able to click the incident icon on the map to get more detailed information about the incident. It appeared that there had been a multi-vehicle accident that had been moved to the right shoulder by CHP and FSP. This meant that not only were the disabled vehicles in the right shoulder, but also CHP vehicles and an FSP vehicle. Ricardo also noticed on the ICMS map that an MTS bus was approaching the incident area. The Dispatcher informed the next *Rapid* bus to enter the 805 at their final stop that there is an incident on the route via radio or mobile data terminal text message.

Ricardo continued to monitor the situation to determine if he needed to direct any other approaching buses out of the shoulder. Ricardo alerted two more approaching buses to exit the shoulder. Once the incident cleared from ICMS, Ricardo no longer needed to warn approaching buses about that particular incident.

Operations Supervisor

As an Operations Supervisor, Amy is made aware of many field operations issues every day. Because of her many, and varied duties, both in the office and in the field she does not necessarily respond to each one individually. In fact, many field operations issues are coordinated between the bus operator and the Dispatchers, and do not require a specific response from Amy. If there is a specific on-going issue that requires Amy's attention, or an incident involving one of the bus operators for whom she has supervisorial responsibility, she will respond and provide direction and input as appropriate.

Incidents and other issues (not involving an MTS transit vehicle) that cause short term temporary re-routing of buses on local roads are sometimes cause for Amy's immediate response. However, because of the fast pace, and dynamic environment of the bus on shoulder operations on the freeway, she typically does not even know about shoulder obstruction events because the bus operator typically re-enters the general-purpose lanes and then diverges back onto the shoulder after passing the blockage without reporting the event. Unless there is a specific on-going issue, or there is an incident involving one of her subordinates, Amy typically does not know about the event, nor does it require a response.

California Highway Patrol

James is a California Highway Patrol (CHP) officer that works out of the San Diego office. The San Diego office has primary patrol responsibility for twelve different freeways that pass through the cities of San Diego, Chula Vista, and National City, as well the unincorporated communities within and immediately

adjacent to those three cities. James frequently patrols on I-805 and SR-94 where MTS buses operate on the shoulder. James and some of his colleagues attended a training session at MTS facilities to learn about the operations policies and procedures for the MTS bus on shoulder operations. He has a basic understanding of the program, the criteria for the buses operating on the shoulder, and what he should be looking out for to ensure his safety, the safety of the motoring public, and the safety of MTS passengers and drivers. Safety is always James' primary consideration in all of his activities on the job.

When James is on the shoulder performing enforcement activities, or incident response, he is aware of the possibility of buses operating on the shoulder.

He understands that with the bus on shoulder operations, he is under no obligation to perform his duties in any way other than in accordance with CHP policies, procedures, and safe practices. However, he does try to expedite incident clearance and enforcement activities whenever possible, and especially in the peak periods when he knows there is a greater likelihood of buses operating on the shoulder. From time to time he is able to move simple enforcement activities off the freeway all together.

As time and the urgency of any given situation allows, if there is a concern with the bus on shoulder operations, James will apprise the CHP dispatcher of his activities and/or obstructions on the shoulder, as it may relate to the bus on shoulder operations. As time and the urgency of any given situation allows, CHP dispatch will then notify MTS dispatch of the activities and/or obstructions impacting the shoulder. James is able to discern between a location where activities and/or obstruction are on a relatively straight portion of the roadway, with good sight distance and visibility, with a location where sight distance for approaching buses operating on the shoulder may not be as good. In instances where sight distance is not as good for approaching buses operating on the shoulder, James will notify CHP dispatch of his concern, and will request notification of the activities and/or obstruction be made to MTS dispatch, to be passed on to approaching bus operators. In such situations, James will also expedite clearance of the shoulder in a safe manner, and in accordance with CHP policies and procedures, to minimize his exposure, and that of any other parties or objects on the shoulder. James can also utilize the services of Freeway Service Patrol (FSP) to expedite clearance. It may also be expedient, as available resources allow, to have FSP post a FSP vehicle upstream of an obstacle in the shoulder, with emergency lights activated, to better identify and provide advanced warning of obstacles on the shoulder. However, such an arrangement would be subject to the judgement of the CHP officer on scene, available resources, and the ability of CHP and FSP to coordinate a safe deployment.

Caltrans Maintenance

Tammy is a Maintenance Supervisor for Caltrans District 11. As a maintenance Supervisor, she manages four roadway maintenance crews on state highways in the central area of San Diego County. Basic roadway maintenance may include guardrail repair, pothole repair and patching, small paving projects, and repair and replacement of roadside signs and sign posts. The maintenance crews also have a regular rotation where they are assigned to pick up debris along the roadway, sometimes in support of sweeping operations. From time to time Tammy has to dispatch a road maintenance crew to assist with clean up after the clearance of an incident.

Yesterday afternoon Tammy received a work order to dispatch a crew to southbound I-805, just south of SR-94, to clear debris from the shoulder area. A call came directly from MTS dispatch to Caltrans Maintenance dispatchers. One of the MTS bus operators driving on the shoulder encountered the debris and alerted MTS dispatch at their first stop after exiting the BOS operations area. It appeared to be the front bumper from a car, and some various other assorted sharp plastic parts, and broken glass. The maintenance crew received instruction to go to the location of the debris immediately, and clear the debris from the shoulder as soon as possible.

All of the maintenance crew lead persons attended a training session at MTS facilities to learn about the operations policies and procedures for the MTS bus on shoulder operations. The lead persons all have a basic understanding of the program, the criteria for the buses operating on the shoulder, and what they and their crews should be looking out for to ensure their safety, the safety of the motoring public, and the safety of MTS passengers and drivers. Safety is always Caltrans' primary consideration in all of their activities in the field.

When the road maintenance crews are on the shoulder performing maintenance activities they are aware of the possibility of buses operating on the shoulder. They understand that with the bus on shoulder operations, they are under no obligation to perform their duties in any way other than in accordance with Caltrans policies, procedures, and safe practices. However, they do try to expedite maintenance and repair activities whenever possible, and especially in the peak periods when they know there is a greater likelihood of buses operating on the shoulder. When the Caltrans maintenance crews are performing work on the shoulders of the freeways on which MTS buses operate, the Caltrans crews alert their dispatchers, and ask that the information be conveyed to MTS dispatch, and on to the bus operators, as appropriate.

The Caltrans crews are able to discern between a location where activities and/or obstruction are on a relatively straight portion of the roadway, with good sight distance and visibility, with a location where sight distance for approaching buses operating on the shoulder may not be as good. In instances where sight distance is not as good for approaching buses operating on the shoulder, Caltrans crews will notify Caltrans maintenance dispatcher of their concern, and will request notification of the activities and/or obstruction be made to MTS dispatch, to be passed on to approaching bus operators. In such situations, Caltrans will place vehicles and equipment such that as much advance warning of the shoulder blockage is given as is possible, and in accordance with Caltrans policies and procedures. Tammy's maintenance crews often work in concert with CHP and FSP personnel, and may from time to time request support of shoulder clearance activities.

MTS Maintenance

MTS maintenance staff respond to perform repairs when MTS *Rapid* buses are disabled in the field. Similar to FSP and CHP personnel, MTS maintenance has a basic understanding of the program, the criteria for the buses operating on the shoulder, and what he should be looking out for to ensure his safety, the safety of the motoring public, and the safety of MTS passengers and drivers. Safety is always his primary consideration in all of his activities on the job.

Freeway Service Patrol

Jose is a Freeway Service Patrol (FSP) driver that is assigned to the I-805 project area. Jose frequently patrols on I-805 and SR-94 where MTS buses operate on the shoulder. Jose and some of his colleagues

attended a training session at MTS facilities to learn about the operations policies and procedures for the MTS bus on shoulder operations. He has a basic understanding of the program, the criteria for the buses operating on the shoulder, and what he should be looking out for to ensure his safety, the safety of the motoring public, and the safety of MTS passengers and drivers. Safety is always Jose's primary consideration in all of his activities on the job.

When Jose is on the shoulder assisting a motorist or the CHP, he is aware of the possibility of buses operating on the shoulder. He understands that with the bus on shoulder operations, he is under no obligation to perform his duties in any way other than in accordance with FSP policies, procedures, and safe practices. However, he does try to expedite incident clearance and assistance activities whenever possible, and especially in the peak periods when he knows there is a greater likelihood of buses operating on the shoulder. From time to time he is able to move simple motorist assistance activities off the freeway all together.

As time and the urgency of any given situation allows, if there is a concern with the bus on shoulder operations, Jose will apprise the FSP dispatcher of his activities and/or obstructions on the shoulder, as it may relate to the bus on shoulder operations. As time and the urgency of any given situation allows, FSP dispatch will then notify MTS dispatch of the activities and/or obstructions impacting the shoulder. Jose is able to discern between a location where activities and/or obstruction are on a relatively straight portion of the roadway, with good sight distance and visibility, with a location where sight distance for approaching buses operating on the shoulder may not be as good. In instances where sight distance is not as good for approaching buses operating on the shoulder, Jose will notify FSP dispatch of his concern, and will request notification of the activities and/or obstruction be made to MTS dispatch, to be passed on to approaching bus operators. In such situations, Jose will also expedite clearance of the shoulder in a safe manner, and in accordance with RSP policies and procedures, to minimize his exposure, and that of any other parties or objects on the shoulder. He may also post his FSP vehicle upstream of an obstacle in the shoulder, with emergency lights activated, to better identify and provide advanced warning of obstacles on the shoulder. However, such an arrangement would be subject to the judgement of the CHP officer on scene, available resources, and the ability of CHP and FSP to coordinate a safe deployment.

Caltrans RMIS/ATMS TMC Operator

Kwame monitors RMIS and ATMS for ramp metering and freeway operations. On a daily basis, Kwame posts messages on the I-805 CMS sign when there are downstream incidents. These CMS messages take precedence to the BOS warning messages, but the BOS warning messages may be attached as a second page to the incident message, warning drivers to watch for BOS operations.

Pilot Analyst(s)

On a weekly basis, Susan evaluates AVL, TSP, LDW, BSD, and FCW events and data along the BOS route. Susan evaluates the system effectiveness in a variety of ways, including by Freeway Segment, Route Number, Run Number, Time of Day, or other user defined scenarios. Susan takes note of all reported incidents and FSP events on I-805 in performing her analysis.

System Integrators/Vendors

Once the system is installed, tested, and certified by SANDAG, MTS, and Caltrans to be operational, the system integrators and vendors are not involved in day-to-day operations. The system integrators ad vendors respond to trouble calls and repairs or replaces equipment or software as necessary.

7.7 Scenario – Operations During Planned Construction

Bus Operator

When Michelle reported to work this morning, she received a notification from Dispatch that there is a planned construction project beginning this week on the northbound side of I-805, at the East 8th Street bridge. Caltrans is starting a bridge rehabilitation project that will last approximately eight weeks. It is anticipated that the shoulder area on the bridge will be closed for approximately six of the eight weeks, starting next week. Later in the morning Michelle sees Amy, her operations supervisor, at Michelle's Downtown layover location. Michelle and Amy discuss bus on shoulder operations during construction on the East 8th Street bridge. Amy and Michelle agree that since the buses are usually on the shoulder for a short distance before they get to the East 8th Street bridge, that the buses should hold off on diverging onto the shoulder until after the bus passes the East 8th Street bridge construction area. They thought that there was no sense in traveling a short distance on the shoulder, and then having to make the merge back into the general-purpose lanes.

The next morning, all of the bus operators that drive on the South Bay *Rapid* route receive a Route Bulletin that reiterates the East 8th Street bridge rehabilitation project, and its associated construction impacts. The Bulletin directs drivers to not drive on the shoulder until after passing the East 8th Street bridge construction zone, until further notice. The following week, the Route Bulletin goes into effect, concurrent with the planned shoulder closure. Michelle and the other drivers have had advanced warning of the planned construction closure, and have responded according to the official directive in the Route Bulletin from MTS Operations supervisors and management.

Dispatcher

Ricardo received the same initial notification as the bus operators regarding the construction project on I-805 at the East 8th Street bridge. He also received the same Route Bulletin the following day, which provided operational direction to the bus operators on the South Bay *Rapid* route. He and the other Dispatchers received a further briefing from the Dispatch Manager the following day just to make sure everyone clearly understood the Route Bulletin. Ricardo understands that he and the other Dispatchers will be the first line of inquiry from bus operators in the field, if there are any questions, or if there is anything unclear about the conditions in the field, or the Route Bulletin itself. It is imperative that the Dispatchers are clear on the purpose and intent of the directives in the Route Bulletin.

Operations Supervisor

On the day the initial notification regarding the I-805 East 8th Street bridge rehabilitation project was circulated, Amy drove to the Downtown layover area for the South Bay *Rapid* bus operators to meet with Michelle. She respects Michelle's skills behind the wheel of the bus, as well as her opinions on operational matters, from the bus operator's perspective.

Amy and Michelle discuss bus on shoulder operations during construction on the East 8th Street bridge. Amy and Michelle agree that since the buses are usually on the shoulder for a short distance before they get to the East 8th Street bridge, that the buses should hold off on diverging onto the shoulder until after the bus passes the East 8th Street bridge construction area. They thought that there was no sense in traveling a short distance on the shoulder, and then having to make the merge back into the general-purpose lanes.

After that discussion with Michelle, which reinforced Amy's thoughts, Amy returned to the Dispatch center and met with a Dispatch supervisor and an Operations Manager. She relayed the discussion she had with Michelle, and her conclusion as to how best to handle the construction activities and shoulder closure. Both the Dispatch supervisor and the Operations Manager concurred with Amy and Michelle's assessment, and directed Amy to develop the Route Bulletin for the South Bay *Rapid* bus operators and the Dispatchers. All appropriate approvals and signatures were received that same afternoon, and the Route Bulletin was circulated the following morning.

Over the next couple days, Amy reached out to several of the other South Bay *Rapid* bus operators to make sure that all were aware of the Route Bulletin, and to answer any questions that they may have regarding operational procedures during the planned construction activities. Amy also reached out to a few of the Dispatchers to make sure they were all on the same page.

California Highway Patrol

James frequently patrols on I-805 and SR-94 where MTS buses operate on the shoulder. During the I-805 East 8th Street bridge rehabilitation project, James does his best to perform enforcement activities outside of the construction area. He also performs incident response in and around the construction zone and is aware due to the training that BOS operations will not be taking place depending on the location of the construction. As James encounters the bus from behind with lights and sirens active, the bus is obligated to merge back into the general traffic lanes to allow James to pass.

He understands that with the bus on shoulder operations, he is under no obligation to perform his duties in any way other than in accordance with CHP policies, procedures, and safe practices. However, he does try to expedite incident clearance and enforcement activities whenever possible, and especially in the peak periods when he knows there is a greater likelihood of additional impacts due to incidents that occur in the construction area.

Caltrans Maintenance

Caltrans Maintenance staff does not perform routine maintenance activities in active construction zones and avoid routine maintenance activities just before or after construction areas. Maintenance understands that BOS operations are either active or inactive based on the location of the construction zone within the overall BOS route on I-805.

MTS Maintenance

MTS maintenance staffs respond to perform repairs when MTS *Rapid* buses are disabled in the field, even in an active construction zone. Similar to FSP and CHP personnel, his safety, the safety of the motoring public, and the safety of MTS passengers and drivers is always his primary consideration in all of his activities on the job when repairing MTS *Rapid* buses in the field.

Freeway Service Patrol

Jose is a Freeway Service Patrol (FSP) driver that is assigned to the I-805 project area. Jose frequently patrols on I-805 and SR-94 where MTS buses operate on the shoulder. Jose will assist motorists in an active construction zone or assist CHP as needed. When Jose is on the shoulder assisting a motorist or the CHP in an active construction zone, he is aware that buses will not be operating on the shoulder. He performs his duties in accordance with FSP policies, procedures, and safe practices. However, he does try to expedite incident clearance and assistance activities whenever possible.

Caltrans TMC Operators

Kwame monitors RMIS for ramp metering. Jose monitors ATMS for CMS messaging and other freeway devices. On a daily basis, Jose posts messages on the I-805 CMS sign when there are construction zones downstream of the CMS. These CMS messages take precedence to the BOS warning messages, but the BOS warning messages might be attached as a second page to the incident message, warning drivers to watch for BOS operations if the location of the construction would allow BOS operation. If the construction zone will disallow BOS operation, Jose removes the warning message for BOS from the message rotation.

Pilot Analyst(s)

On a weekly basis, Susan evaluates AVL, TSP, LDW, BSD, and FCW events and data along the BOS route. Susan evaluates the system effectiveness in a variety of ways, including by Freeway Segment, Route Number, Run Number, Time of Day, or other user defined scenarios. Susan takes note of all construction activities on I-805 in performing her analysis.

System Integrators/Vendors

Once the system is installed, tested, and certified by SANDAG, MTS, and Caltrans to be operational, the system integrators and vendors are not involved in day-to-day operations. The system integrators and vendors respond to trouble calls and repairs or replaces equipment or software as necessary.

7.8 Scenario – Training

Bus Operator

Michelle learned in the classroom training about the operating rules for BOS and the technology systems in place to assist her. She learned that the FCW, LDW, and BSW systems will provide audio, visual and haptic feedback to improve safety. She also learned that the TSP system on northbound I-805 will hold the ramp meters in red when she is approaching the ramp on the shoulder. She is still vigilant for drivers that will not obey the red indication. She also learned that the southbound ramps will only have warning messages for the drivers approaching the freeway from the ramp and that she should not expect them to yield, but some drivers may stop suddenly or take different actions than normal in response to the BOS.

Michelle learned in the classroom training that obstacles on the shoulder, particularly disabled vehicles and law enforcement vehicles performing enforcement activities, would pose a challenge to the effectiveness of the shoulder running operations. She and the other bus operators were instructed to beware of such obstacles, and when operating on the shoulder, to be prepared to leave the shoulder area in the event they encounter any type of obstacle on the shoulder. The MTS Dispatchers try to give forewarning of obstacles on the shoulder at the beginning of the shift or at any stop. It will likely be more common that Michelle will encounter blockages or issues with shoulder running and report these issues to the dispatcher at her next stop.

Michelle performed several training runs on I-805 on the proposed South Bay *Rapid* service route with BOS operations with MTS Operations personnel but no passengers on board.

Dispatcher

Ricardo, along with the other bus dispatchers, attended the bus on shoulder classroom training on the operational polices, and safety practices and procedures for operating buses on the freeway shoulder. When the bus operators did the behind the wheel training, the bus dispatchers rode along on the bus and observed the training and driving, but did not perform the behind the wheel training itself. These training activities provided the policy and procedure background needed by the bus dispatchers to be able to provide direction to the bus operators when needed; and it also provided them with some practical hands-on training so that they would better understand the driving challenges faced by the bus operators while driving the bus on the shoulder of the freeway. MTS Dispatchers will be trained to understand the new "Potential CHP activity on shoulder" message in the MTS RTMS or secure web page indicating BOS status. The MTS Dispatchers may inform BOS drivers of potential CHP activity on the route via radio or mobile data terminal text display.

Operations Supervisor

Amy attended the bus on shoulder classroom training, along with the bus operators and the Dispatchers. As a front line supervisor, it is imperative that she understands the operational polices, and safety practices and procedures for operating buses on the freeway shoulder in great detail. Amy also participated in the bus simulator training, as well as the behind the wheel training. She thought it was important to experience operating the bus on the freeway shoulder first hand. In addition to her own behind the wheel training, she also did some "ride alongs" with some of the drivers she supervises so that she has a better feel for the comfort level of the bus on shoulder operations for the drivers.

California Highway Patrol

James and other CHP personnel attended the BOS classroom training informing them of BOS operations policies and practices on I-805.

Caltrans Maintenance

Caltrans maintenance staff attended the BOS classroom training informing them of BOS operations policies and practices on I-805.

MTS Maintenance

MTS maintenance staff attended the BOS classroom training informing them of BOS operations policies and practices on I-805.

Freeway Service Patrol

FSP maintenance staff attended the BOS classroom training informing them of BOS operations policies and practices on I-805.

Caltrans TMC Operators

Kwame, Jose and other Caltrans TMC operators attended the BOS classroom training informing them of BOS operations policies and practices on I-805. They helped define the formatting and procedures for inserting the BOS operating message into the CMS display message queue of the ATMS. They helped define the specific exceptions for message insertion for BOS during incidents and planned construction.

Pilot Analyst(s)

Susan attended the BOS classroom training to understand the operating policies for BOS and how her analysis will be important to show the benefits of the program.

System Integrators/Vendors

The system integrators and vendors provide training to SANDAG, MTS, Caltrans, and associated stakeholders on system operation, installation, configuration, reporting, and analysis. The system integrators and vendors respond to trouble calls and repairs or replaces equipment or software as necessary. The system integrators and vendors assist MTS, Caltrans, and SANDAG in preparing training materials for additional agency staff.

7.9 Scenario – Maintenance

Bus Operator

Michelle is responsible for identifying any potential anomalies or malfunctions of the BSD, LDW, and FCW driver assistance systems and reporting potential failures to the Operations Supervisor. Michelle reports any mechanical or operational issues of the bus with the MTS Dispatcher. Michelle safely operates her bus to the shoulder for maintenance response.

Dispatcher

The MTS dispatcher records any report of maintenance issues from the bus drivers and dispatches maintenance to repair the bus, as well as additional bus to take the passengers on the failed bus to their destination.

Passenger

Passenger has no role in maintenance.

Operations Supervisor

Amy coordinates field maintenance dispatch and pick-up of passengers on failed buses.

California Highway Patrol

At a future time, there may be a role for the CHP CAD vendor.

Caltrans Maintenance

Caltrans maintenance is responsible for repair of technical equipment including ramp metering field equipment, signals, cabinets, extinguishable message signs, and CMS. Caltrans maintenance is responsible for repair and maintenance of roadway surfaces, signs, and striping.

Caltrans maintenance will be responsible for roadside to vehicle communications systems and associated hardware connecting the roadside communications to the ramp meter after the Pilot project is concluded successfully. System Integrators and Vendors will be responsible for maintenance of the equipment and systems (through SANDAG) during the Pilot project.

MTS Maintenance

MTS maintenance staff is responsible for repair of all bus hardware and components, including the LDW, FCW, BSD, and TSP components and communication systems after the Pilot project is concluded successfully. System Integrators and Vendors will be responsible for maintenance of the equipment and systems (through SANDAG) during the Pilot project.

Freeway Service Patrol

FSP provides maintenance support to motorists.

Caltrans TMC Operators

Kwame, Jose and other Caltrans TMC operators are responsible for identifying failures in ramp metering and CMS field equipment and informing maintenance of the need for repair. Kwame, Jose and other Caltrans TMC operators are responsible for identifying communications failures to the field

processors and roadside communications systems and informing systems integrator of the need for repair.

Pilot Analyst(s)

Susan has no role in maintenance, although in the conduct of her weekly analysis reports she may find anomalies and bring them to the attention of the system integrators, vendors, SANDAG, MTS, and Caltrans for troubleshooting and investigation of possible system failures.

System Integrators/Vendors

The system integrator responds to trouble calls and repairs or replaces equipment or software as necessary during the Pilot project (as contracted by SANDAG) and according to maintenance agreements with appropriate agencies during future operational phases.

8 SUMMARY OF IMPACTS

8.1 Analysis of the Proposed System

The BOS system is anticipated to improve the travel time reliability of the *Rapid* service on I-805. Welcomed outcomes may include an increase in Rapid ridership and public request for additional BOS services throughout the region. As a Pilot project, technical analysis of the technology components will also be assessed to determine the effectiveness of the specific approach. Analysis activities of the effectiveness will include:

1. A quantitative before and after assessment of *Rapid* bus travel performance along the route
2. A quantitative assessment of the performance characteristics of the technology subsystems
3. A quantitative assessment of safety performance of BOS operations
4. A qualitative assessment of rider satisfaction and public sentiment
5. A qualitative assessment of bus operator satisfaction and sentiment
6. A qualitative assessment of motorist satisfaction and sentiment of ramp operation
7. A qualitative assessment of burden on Caltrans transportation system management and operations processes and personnel due to the BOS operation
8. A qualitative assessment of Pilot analyst(s) access to operational data for effectiveness analysis
9. A qualitative assessment of project "lessons learned"

8.2 Metrics for Assessing System Performance

Table 3. Metrics for Assessing System Performance

Category	Performance Metric
Technology effectiveness	• Number of TSP requests submitted successfully (by location) • Number of TSP requests successfully served (by location) • Number of TSP requests successfully cancelled (and number of requests cancelled by ramp via timeout) • Average and variability of range of vehicle-to-roadside bus-ramp first-contact connection (by location)

	• Number of Probe Data messages received successfully (by location) • Number of BSM trajectories received successfully (by location) • Average and variability of length of BSM trajectories and number of BSMs in each trajectory (by location) – related to average and variability of range of Bus-roadside connection, signal strength, interference, etc. • Estimated lane precision from location data in PDMs and BSM trajectories • % of route coverage by PDMs
Rapid Bus Travel Reliability	• Percent trips above and below 35 mph average travel speed for route • On time performance (by TOD, DOW, etc.) • Buffer time for *Rapid* Route (by TOD, DOW, etc.) Travel time between the BOS operation entrance point on I-805 to the exit point on I-805 (by direction, TOD, DOW, etc.)
Safety	• Crash rate (by location, TOD, DOW, etc) • Number and type of Driver Assistance System warnings (by location, TOD, DOW, etc.) • Qualitative: number of DAS warnings displayed considered "false alarms" by operators • Number of egress events from shoulder due to obstacle, CHP activity, or other • Smoothness of ingress/egress maneuvers to and from the shoulder (by driver) • Frequency of hard braking events and accel/decel profiles (by driver; in/out of

	shoulder; by location – in ramp conflict zone and otherwise)
Surface quality	• Estimated surface quality from vertical accelerometer data in BSMs, e.g. potholes and surface deterioration (in shoulder-out of shoulder) • Surface quality differences during rain events i.e. “pooling” or “ponding”, potholes (in/out of shoulder)
Public response	• Survey of riders • Survey of ramp meter users • Survey of I-805 commuters • Customer comfort: Smoothness of ingress/egress maneuvers to and from the shoulder (by driver) • Customer comfort: Frequency of hard braking events and accel/decel profiles (by driver)
Agency response	• Survey and interviews of bus operators • Survey and interviews of relevant Caltrans, MTS, and SANDAG operations positions

Success will be determined on each metric based on a combination of the quantitative and qualitative results of the Pilot analysis in the project assessment report.

9 APPENDICES

9.1 Glossary of terms

511	A free phone and web service that consolidates San Diego's regional transportation information
AB3418E	A Caltrans standard protocol for communicating status or commands from a central system to a field device, such as a ramp meter
Amber alert	A message displayed on a message sign on a freeway warning motorists to look for a specific vehicle license plate, model, and make which may contain an abducted child
Auxiliary lane	A lane on a freeway that allow simultaneous merging off of the freeway to an off-ramp and merging on to the freeway from an on-ramp
Cabinet	The enclosure, typically metal, containing hardware and software components for controlling field devices, such as ramp meters or changeable message signs
Conflict	An event between two or more vehicles where if one vehicle does not take evasive action of some kind, they will collide
Cold-plane	A structural roadway engineering term describing something you do to a pavement to make it tough enough for Bus on Shoulder operation
Firmware	A type of software that provides control and monitoring of systems in field environments such as ramp meters, traffic signals, and message signs. Typically firmware
Inside shoulder	Left-hand-side lane on the freeway typically reserved for emergency use only
NTCIP	A national standard protocol for communicating status or commands from a central system to a field device, or from one system to another system
Off-the-shelf	A system either hardware or software that can be purchased from multiple competitive vendors without modifications for a specific use
On time performance	The status of a transit vehicle arriving on or before its scheduled travel time from an origin to a destination
Outside shoulder	Right-hand-side shoulder on the freeway typically reserved for emergency use, maintenance vehicles, and enforcement activities
Peak period	The time of day when most traffic congestion occurs on a recurring basis
Probe Vehicle Data	A record of a trajectory of location, speed, acceleration, and other operational characteristics data of the bus along its route.
Probe Management Message	A roadside command broadcast at network boundaries (i.e. Rural, Suburban, Urban, Freeway) to modify the frequency of collection of Probe Vehicle Data.

Ramp meter	The traffic signal at an on-ramp to a freeway that requires approaching traffic to stop before entering the freeway
Silver Alert	A message displayed on a message sign on a freeway warning motorists to look for a specific vehicle license plate, model, and make that may contain an impaired older driver
Transit priority	A process by which transit vehicles receive preferential green time at a traffic signal
Tweet	A 140-character maximum message sent by a person on a mobile device or computer that can be received by multiple people on mobile devices or computers that subscribe to messages from that person (i.e. "follow")
Twitter handle	The alias of the person sending tweets, formatted as @JoeIsImportant

9.2 Abbreviations list

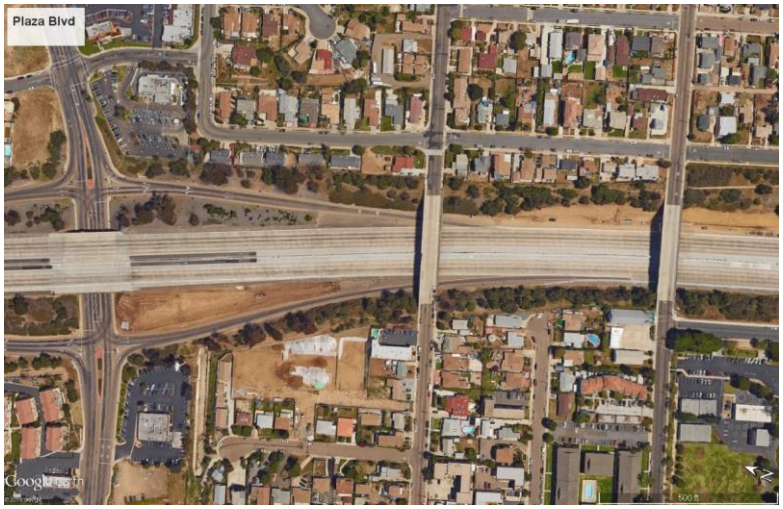
ATDM	Active Traffic Demand Management
ATMS	Advanced Transportation Management Software
AVL	Automated Vehicle Location
BSD	Blind Spot Detection
BSM	Basic Safety Message
BOS	Bus on Shoulder
c-PeMS	Corridor Performance Measurement System
CAD	Computer Aided Dispatch
C2C	Center to Center
CBA	Collective Bargaining Agreement
CHP	California Highway Patrol
CMS	Changeable Message Sign
DAR	Direct Access Ramp
ESAL	Equivalent Six Axle Load
FCW	Forward Collision Warning
FSP	Freeway Service Patrol
FTA	Federal Transit Administration
GID	Geometric Intersection Description
GPS	Global Positioning System
HOV	High Occupancy Vehicle

LDW	Lane Departure Warning
MDT	Mobile Data Terminal
MTS	Metropolitan Transit System
NTCIP	National Transportation Communications Information Protocol
PeMS	Performance Measurement System
PVD	Probe Vehicle Data
RMIS	Ramp Metering Information System
RSE	Roadside Equipment
SAE	Society of Automotive Engineers
SANDAG	San Diego Association of Governments
SDRMS	San Diego Ramp Metering System
t-PeMS	Transit Performance Measurement System
TCRP	Transit Cooperative Research Program
TMC	Traffic Management Center
TSP	Transit Signal Priority
URMS	Universal Ramp Metering System
V2I	Vehicle-To-Infrastructure

9.3 Agency Contact list

SANDAG	San Diego Association of Governments
MTS	San Diego Metropolitan Transit System
Caltrans	California State Department of Transportation
USDOT	United States Department of Transportation
FTA	Federal Transit Agency

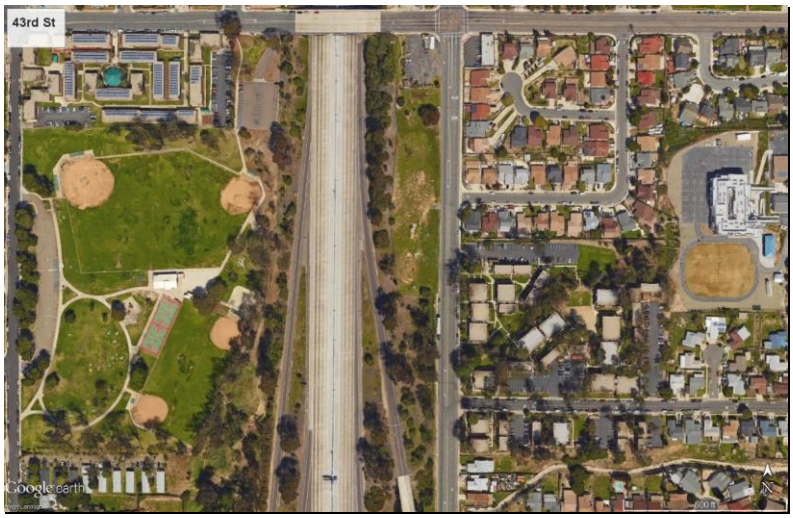
9.4 View of Entrance Ramps



Plaza Blvd Interchange SB On/NB Off

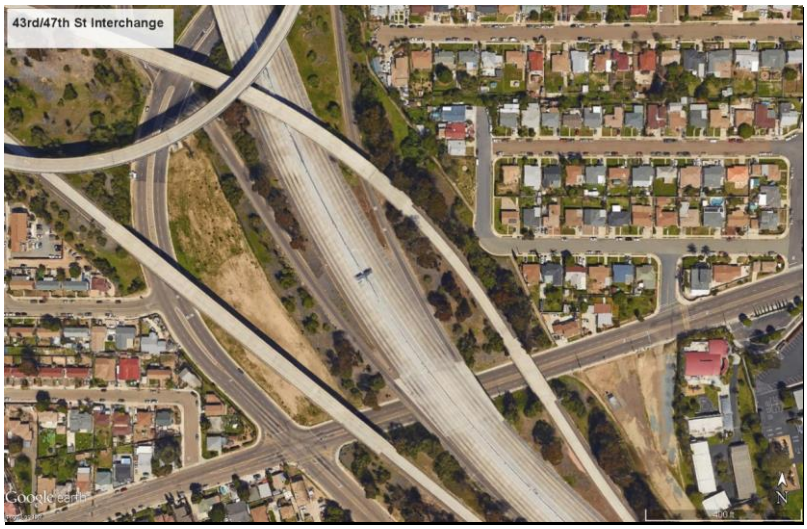
Plaza Blvd Interchange NB On/SB Off

43rd St Interchange SB On/NB Off



43rd St Interchange NB On/SB Off

47th St Interchange SB On/NB Off



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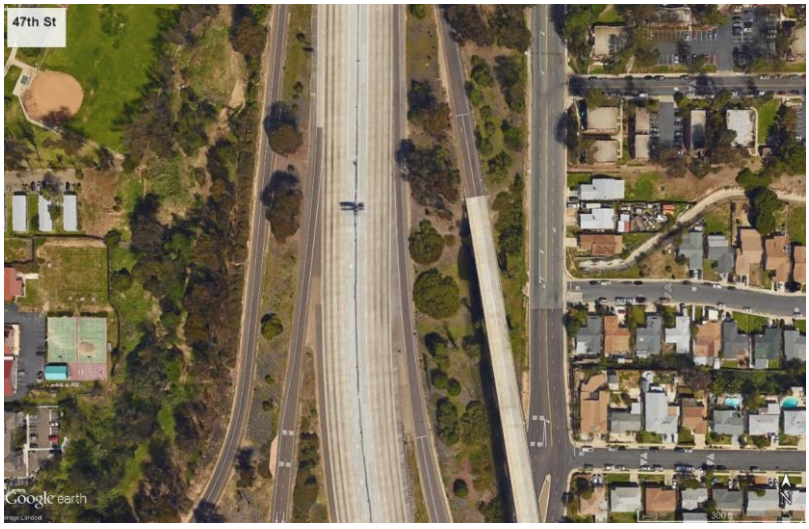
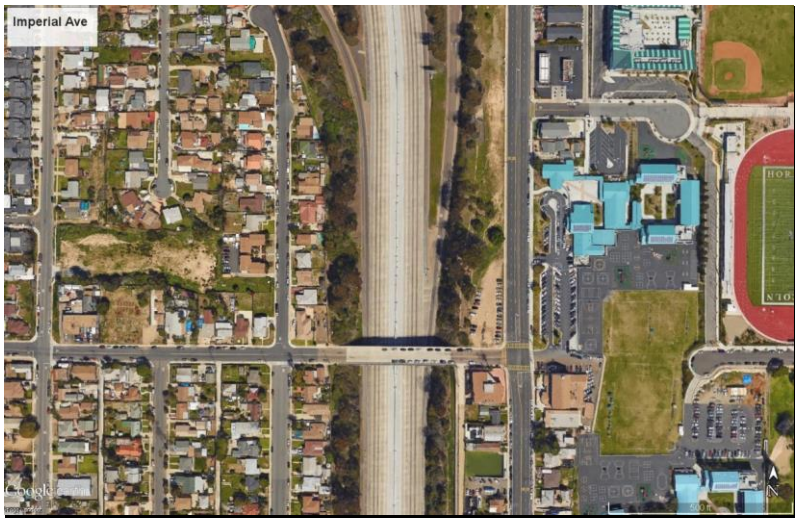


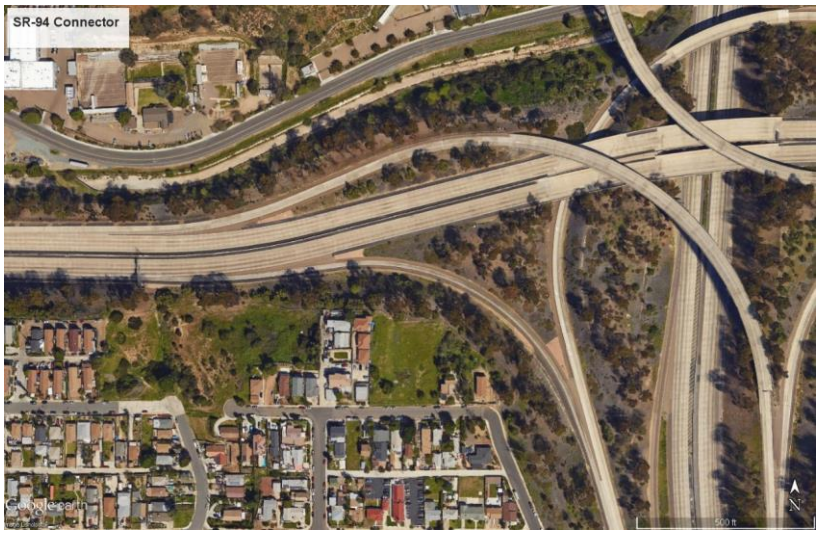


Imperial Ave Interchange NB Off/SB On

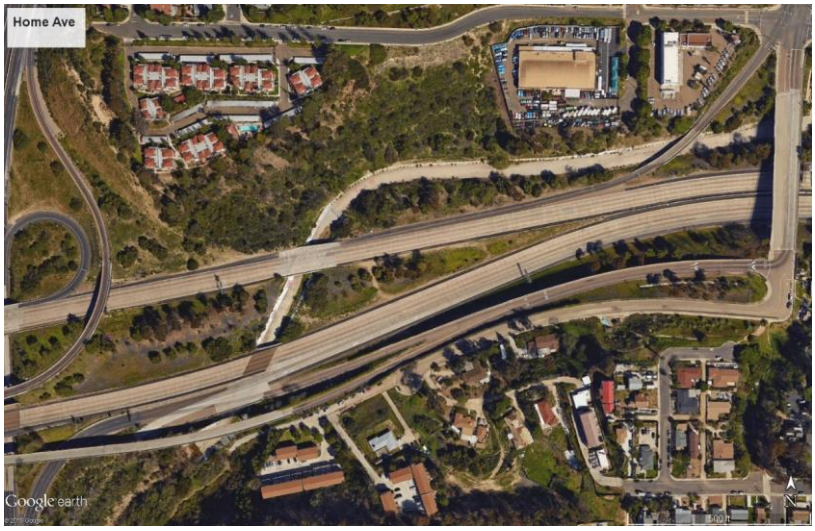
Imperial Ave Interchange SB Off/NB On

Market St Interchange SB On/NB Off

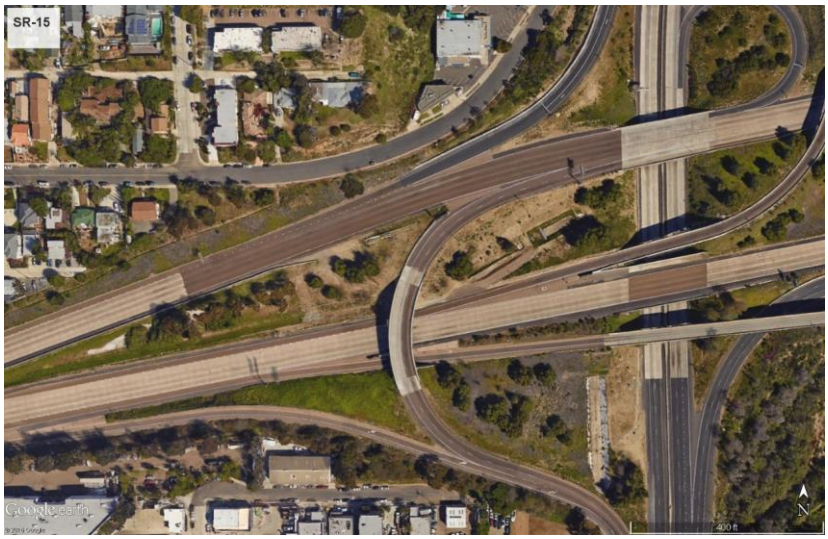
Market St Interchange NB On/SB Off



I-805 NB to SR-94 WB and SR-94 EB to I-805 SB

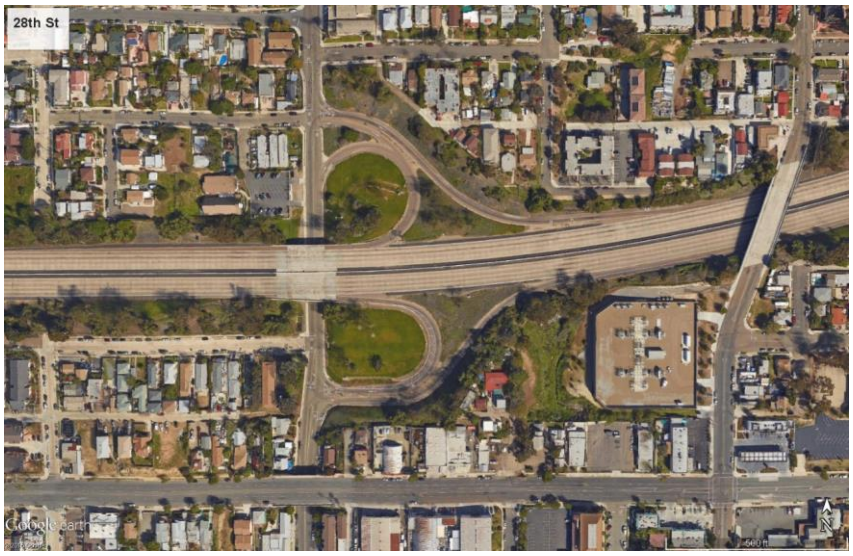


Home Ave Interchange



SR-15 Interchange

Broadway Interchange



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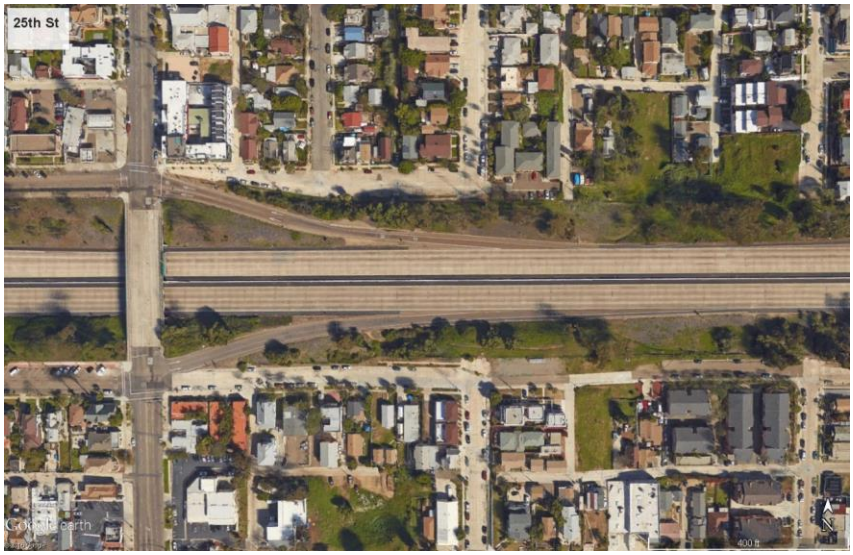

25th St Interchange