Integrated Corridor Management Initiative: Demonstration Phase Evaluation

San Diego Corridor Performance Test Plan

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16. Abstract

This report presents the test plan for conducting the Corridor Performance Analysis for the United States Department of Transportation (U.S. DOT) evaluation of the San Diego Integrated Corridor Management (ICM) Initiative Demonstration. The ICM projects being deployed in San Diego include a suite of strategies aimed at balancing corridor transportation supply and demand to promote overall corridor efficiency and safety. Operational strategies to be deployed in the San Diego I-15 highway corridor include: simulations to predict travel conditions for improved incident response, interdependent response plans among agencies, traffic diversion to strategic arterials, traveler mode shift to the bus rapid transit (BRT) system during major freeway incidents, and comparative travel time information to the public and operating agencies for freeway, HOT lanes, arterial streets, and BRT. Technologies that will be used to carry out these strategies include a Decision Support System, a 511 traveler information system (telephone and website), a regional center-to-center information exchange network, dynamic message signs, adaptive ramp metering, and responsive traffic signals. This Corridor Performance Analysis Test Plan is based on the ICM Initiative Demonstration National Evaluation Framework. This test plan provides an overview of the Corridor Performance Analysis and describes the specific qualitative and quantitative data that will be collected to support the analysis. Data analysis methodologies as well as risks and mitigations associated with this evaluation analysis are also discussed in this test plan.

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LIST OF ABBREVIATIONS

A-PeMS	Arterial-PeMS
AMS	Analysis, Modeling and Simulation
APC	Automatic Passenger counter
AVL	Automatic Vehicle Location
AVO	Average Vehicle Occupancy, average number of persons that occupy vehicles in each vehicle class of interest (e.g., automobiles, carpools, transit, etc.)
BI	Buffer Index, represents the extra time cushion needed during peak traffic periods to prevent being late
BRT	Bus Rapid Transit
Caltrans	California Department of Transportation
CHP	California Highway Patrol
DMS	Dynamic Message Sign
DSS	Decision Support Systems
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GP	General Purpose
GUI	Graphical User Interface
HOT	High-Occupancy Tolling
HOV	High-Occupancy Vehicle
I-5	Interstate 5
I-8	Interstate 8
I-15	Interstate 15
I-805	Interstate 805
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
IMTMS	Intermodal Transportation Management System
iNET	Intelligent NETworks
ITS	Intelligent Transportation Systems
KTT	Knowledge and Technology Transfer
LRT	Light Rail Transit
MCAS	Marine Corps Air Station
MOE	Measure of Effectiveness
MTS	Metropolitan Transit System
NCTD	North County Transit District

O-D	Origin-Destination
OES	Office of Emergency Services
PeMS	Performance Measurement System
PHT	Person-Hours Traveled, total person hours expended traveling on the roadway network in a specified area during a specified time period
PMT	Person-Miles Traveled, a measure of throughput and is the product of passenger throughput times the length of segment of roadway
PT	Person Throughput, total number of people serviced in the segment, O-D pair, or corridor during the analysis period
PTI	Planning Time Index, represents the extra time cushion needed during peak traffic periods to prevent being late
PTT	Person Travel Time
RITA	Research and Innovative Technology Administration
R/T	Real-time
SANDAG	San Diego Association of Governments
SD SAFE	San Diego County Service Authority for Freeway Emergencies
S.R.	State Route
SWITRS	Statewide Integrated Traffic Records System
TASAS	Traffic Accident Surveillance and Analysis System
TMDD	Traffic Management Data Dictionary
T-PeMS	Transit-PeMS
TT	Travel Time, time for a vehicle or a person travel from one point to another
TTI	Travel Time Index, a ratio of the travel time during the peak period to the time required to make the same trip at free-flow speeds
UMD	University of Maryland
U.S. DOT	U.S. Department of Transportation
VHT	Vehicle-Hours Traveled, total vehicle hours expended traveling on the roadway network in a specified area during a specified time period
Vi	Count of Vehicles
VMT	Vehicle-Miles Traveled, a measure of throughput and is the product of passenger throughput times the length of segment of roadway
Volpe Center	John A. Volpe National Transportation System Center
VPHPL	Vehicles per hour per lane
VT	Vehicle Throughput, a measure of the number of vehicles that are served in one direction of a facility during the analysis period
VTT	Vehicle Travel Time

1.0 INTRODUCTION

This report presents the plan for conducting the Corridor Performance Analysis, one of seven analyses that comprise the United States Department of Transportation (U.S. DOT) national evaluation of the San Diego Integrated Corridor Management (ICM) Initiative demonstration phase. The ICM demonstration phase includes multimodal deployments in the U.S. 75 corridor in Dallas, Texas and the Interstate 15 (I-15) corridor in San Diego, California. Separate evaluation test plan documents are being prepared for each site. This document, which focuses on San Diego, is referred to as a "test plan" because, in addition to describing the specific data to be collected, it describes how that data will be used to test various evaluation hypotheses and answer various evaluation questions.

The primary thrust of the national ICM evaluation is to thoroughly understand each site's ICM experience and impacts. However, it is expected that various findings from the two sites will be compared and contrasted as appropriate and with the proper caveats recognizing site differences.

The remainder of this introduction chapter describes the ICM program and elaborates on the hypotheses and objectives for the demonstration phase deployments in Dallas and San Diego, as well as the subsequent evaluation analyses. The remainder of the report is divided into two major sections. Chapter 2 is devoted to the mobility aspects of the Corridor Performance Analysis, including examination of ICM impacts on traffic volumes and speeds, person and vehicular throughput, and transit ridership. Chapter 3 is devoted to the safety portion of the Corridor Performance Analysis, focusing on before-after comparisons of crashes. Both Chapters 2 and 3 include subsections describing the data that will be used, how the data will be analyzed, and risks and mitigations associated with the mobility and safety data.

1.1 ICM Program[1]

Congestion continues to be a major problem, specifically for urban areas, costing businesses an estimated $200 billion per year due to freight bottlenecks and drivers nearly 4 billion hours of time and more than 2 billion gallons of fuel in traffic jams each year. ICM is a promising congestion management tool that seeks to optimize the use of existing infrastructure assets and leverage unused capacity along our nation's urban corridors.

ICM enables transportation managers to optimize use of all available multimodal infrastructure by directing travelers to underutilized capacity in a transportation corridor—rather than taking the more traditional approach of managing individual assets. Strategies include motorists shifting their trip departure times, routes, or modal choices, or transportation managers dynamically adjusting capacity by changing metering rates at entrance ramps or adjusting traffic signal timing plans to accommodate demand fluctuations. In an ICM corridor, travelers can shift

[1] This section has largely been excerpted from the U.S. DOT ICM Overview Fact Sheet, "Managing Congestion with Integrated Corridor Management," http://www.its.dot.gov/icms/docs/cs_over_final.pdf, developed by SAIC for U.S. DOT. At the direction of U.S. DOT, some of the original text has been revised to reflect updates and/or corrections.

to transportation alternatives—even during the course of their trips—in response to changing traffic conditions.

The objectives of the U.S. DOT ICM Initiative are:

- Demonstrate how operations strategies and Intelligent Transportation Systems (ITS) technologies can be used to efficiently and proactively manage the movement of people and goods in major transportation corridors through integration of the management of all transportation networks in a corridor.
- Develop a toolbox of operational policies, cross-network operational strategies, integration requirements and methods, and analysis methodologies needed to implement an effective ICM system.
- Demonstrate how proven and emerging ITS technologies can be used to coordinate the operations between separate multimodal corridor networks to increase the effective use of the total transportation capacity of the corridor.

The U.S. DOT's ICM Initiative is occurring in four phases:

- Phase 1: Foundational Research – This phase researched the current state of corridor management in the United States as well as ICM-like practices around the world; initial feasibility research; and the development of technical guidance documents, including a general ICM concept of operations to help sites develop their own ICM concept of operations.
- Phase 2: Corridor Tools, Strategies and Integration – U.S. DOT developed a framework to model, simulate and analyze ICM strategies, working with eight Pioneer Sites to deploy and test various ICM components such as standards, interfaces and management schemes.
- Phase 3: Corridor Site Development, Analysis and Demonstration – This phase includes three activities:
  1) Concept Development – Eight ICM Pioneer Sites developed concepts of operation and requirements documents.
  2) Modeling – U.S. DOT selected Dallas, Minneapolis and San Diego to model their proposed ICM systems.
  3) Demonstration and Evaluation – Dallas and San Diego will demonstrate their ICM strategies; data from the demonstrations will be used to refine the analysis, modeling and simulation (AMS) models and methodology.
- Phase 4: Outreach and Knowledge and Technology Transfer (KTT) – U.S. DOT is packaging the knowledge and materials developed throughout the ICM Initiative into a suite of useful multimedia resources to help transportation practitioners implement ICM.

An on-going ICM Initiative activity, AMS is very relevant to the evaluation. AMS tools were developed in Phase 2 and used by the sites to identify and evaluate candidate ICM strategies. In Phase 3, the proposed Dallas and San Diego ICM deployments were modeled. As sites further refine their ICM strategies, AMS tools continue to be used and iteratively calibrated and validated, using key evaluation results, in part. The AMS tools are very important to the evaluation for two reasons. First, the evaluation will produce results that will be used to complete validation of the AMS tools, e.g., updating the AMS assumptions related to the percentage of travelers who change routes or modes in response to ICM traveler information. Second, the calibrated AMS tools will serve as a source of some evaluation data, namely the corridor-level, person-trip travel time and throughput measures that are difficult to develop using field data.

1.2 ICM Demonstration Phase Deployments[2]

This section summarizes the San Diego ICM deployment and briefly contrasts it with the Dallas deployment.

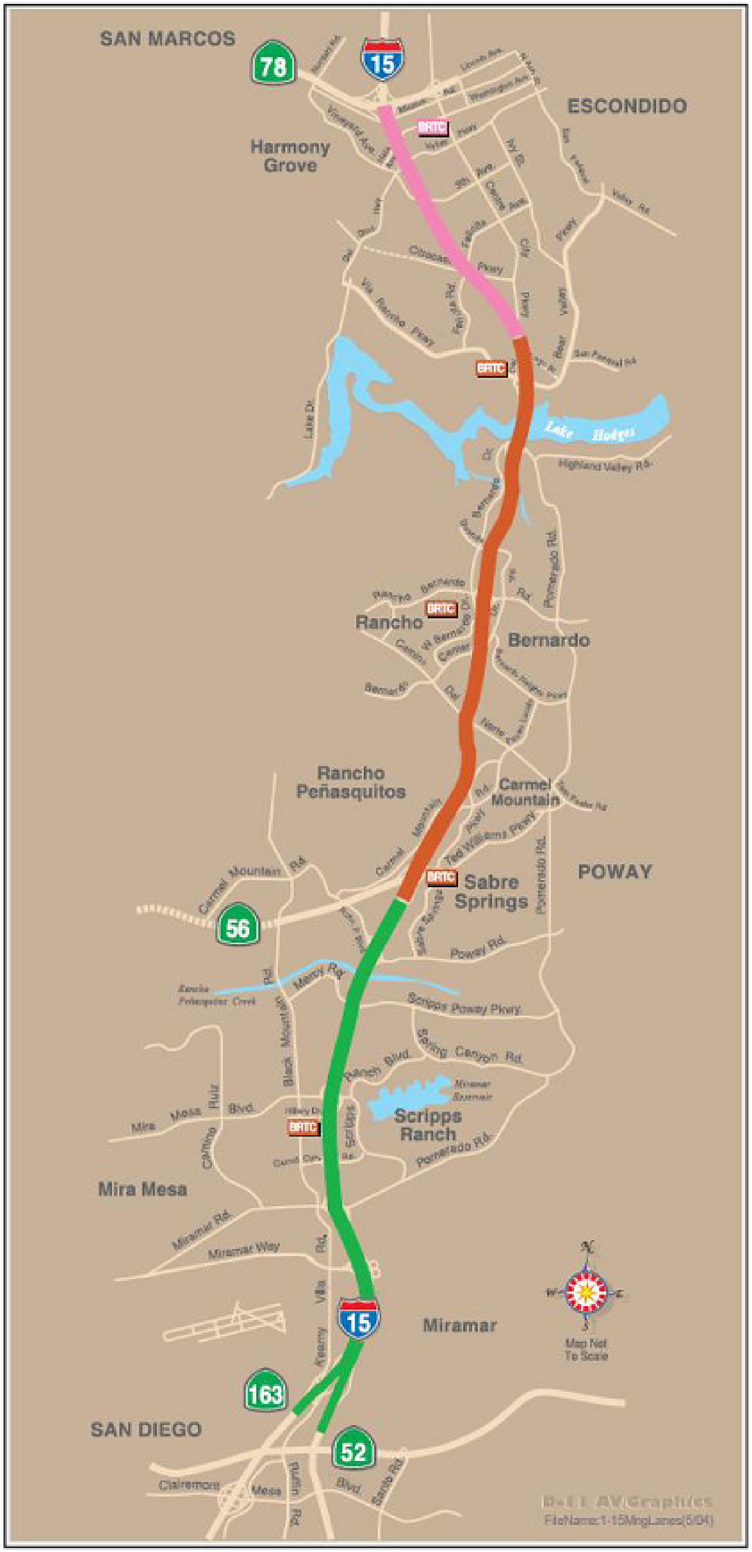
1.2.1 Overview of the San Diego ICM Deployment

The I-15 project is a collaboration led by the San Diego Association of Governments (SANDAG), along with U.S. DOT; the California Department of Transportation; Metropolitan Transit System (MTS); North County Transit District (NCTD); the cities of San Diego, Poway, and Escondido; San Diego County Service Authority for Freeway Emergencies (SD SAFE); County of San Diego Office of Emergency Services (OES); and California Highway Patrol (CHP), in addition to private sector support.

The San Diego ICM corridor includes the portion of I-15, a north-south facility, from State Route (S.R.) 78 in the north to the S.R. 163 interchange in the south, as shown in Figure 1-1. I-15 is a primary artery for the movement of commuters, goods, and services from inland northern San Diego County to downtown San Diego. Weekday traffic volumes range from 170,000 to 290,000 vehicles on the general purpose lanes.

The corridor currently has a 20-mile, four-lane concurrent flow high-occupancy toll/managed lanes facility with two reversible center lanes, the “I-15 Express Lanes.” Approximately 30,000 vehicles use the I-15 Express Lanes during weekdays, and the corridor experiences recurring congestion.

[2] Information in this section has been excerpted from “Integrated Corridor Management,” published in the November/December 2010 edition of Public Roads magazine. The article was authored by Brian Cronin (RITA), Steve Mortensen (FTA), Robert Sheehan (FHWA), and Dale Thompson (FHWA). With the consent of the authors, at the direction of U.S. DOT some updates or corrections have been made to this material.



San Diego Association of Governments, January 2011

Figure 1-1. I-15 Corridor Boundaries of San Diego ICM Deployment

The San Diego ICM focuses on five primary ICM goals to augment technical management, software and systems development, and cutting-edge innovation:

1. The corridor's multimodal and smart-growth approach shall improve accessibility to travel options and attain an enhanced level of mobility for corridor travelers.
2. The corridor's safety record shall be enhanced through an integrated multimodal approach.
3. The corridor's travelers shall have the informational tools to make smart travel choices within the corridor.
4. The corridor's institutional partners shall employ an integrated approach through a corridor-wide perspective to resolve problems.
5. The corridor's networks shall be managed holistically under both normal operating and incident/event conditions in a collaborative and coordinated way.

To achieve these goals, SANDAG and its partnering agencies will contribute $2.2 million for the $10.9 million project. San Diego will use investments in ITS to implement a "smart" transportation management system that combines road sensors, transit management strategies, video, and traveler information to reduce congestion. The smart system will deliver information to commuters via the Internet and message signs, and will enable managers to adjust traffic signals and ramp meters to direct travelers to high-occupancy vehicle (HOV) and high-occupancy tolling (HOT) lanes, bus rapid transit, and other options. Specific examples of practices the San Diego site team intends to employ include the following:

- Provide corridor users with the operational condition of all corridor networks and components, such as comparative travel times, incident information, and expected delays.
- Use a decision support system with real-time simulation, predictive algorithms, and analysis modeling.
- Establish, improve, and automate joint agency action plans for traveler information, traffic signal timing, ramp metering, transit and Express Lanes.
- Identify means of enhancing corridor management across all networks, including shared control multi-jurisdictional coordination of field devices such as lane controls, traveler information messages, traffic signal timing plans, and transit priority.

Technology investments that are being implemented as part of the ICM deployment in San Diego and which will be used to carry out ICM operational strategies include:

- A Decision Support System (DSS) that will utilize incoming monitoring data to assess conditions, forecast conditions up to 30 minutes in the future, and then formulate recommended response plans (including selecting from pre-approved plans) for consideration by operations personnel. Table 1-1 summarizes expected San Diego DSS functionality.

- Enhancement of the Intermodal Transportation Management System (IMTMS) regional information exchange network, a system previously implemented using non-ICM funding and which is being enhanced using ICM funding, depicted in Figure 1-2.
- Adjustments to ramp meter timing to support diversions to or from the freeway
- Lane use modifications, namely the four configurable, managed (variably priced high-occupancy toll) lanes in the I-15 median.
- Upgrades to selected traffic signal systems, including new traffic signal coordination timings and responsive traffic signal control on two arterial streets paralleling I-15.
- Arterial street monitoring system, including additional traffic detectors.

Table 1-1. Summary of San Diego DSS Functionality

Functionality	Summary
Expert-System Based DSS	The Expert System combines a rule base using incident response parameters with knowledge base information on roadway geometry and field device locations to automatically generate response plans consisting of strategies such as dynamic message signs (DMS), signal timing, and ramp metering and incident checklists. The heart of the DSS subsystem within the Integrated Corridor Management System (ICMS) is the ability to analyze collected data, ascertain abnormal or scheduled events, determine appropriate responses, and suggest a set of actions that collectively form a "Response Plan." The Response Plan may be manually or automatically generated, but if automatically generated, will include the capability for human operator review and modification. This is particularly critical for field device (i.e., DMS and camera) control actions.
Real-Time Monitoring of Transportation System Conditions through the DATA-HUB (IMTMS)	The DSS – DATA HUB takes the data received from participating agencies and provides fused data to participating agencies as XML data feeds and to the general public through the regional 511 system. The DSS – DATA HUB will provide for a dynamic, Web-based Graphical User Interface (GUI) to selected agencies for the monitoring of corridor performance and operations. This portion of DSS functionality is the Intelligent NETworks (iNET) program
Real-Time Simulation modeling to help assess impacts of response plans	The DSS will use a micro/meso scale modeling tool to assess the impact of short-term responses to the planned and unplanned events in the corridor (such as the recent wildfires in San Diego). The real-time modeling component will use the DATA-HUB inputs, along with the DSS-Response Plans to generate corridor level impact assessments of response plans.
Offline simulation and modeling to help fine-tune response plans	Response plans will be reviewed periodically using offline simulation and modeling approaches to make changes to the rules of practices, generate modified rules of practice, and assess the performance retroactively of the DSS.
DSS-Network prediction	DSS includes a network prediction capability that looks at capacity and demand conditions across the corridor up to an hour in advance in 15 minute slices. The network prediction looks at estimating demand and the consequent travel conditions across the various modes in the corridor. This information is shared with the corridor operators. The prediction will be refreshed every 3-5 minutes.

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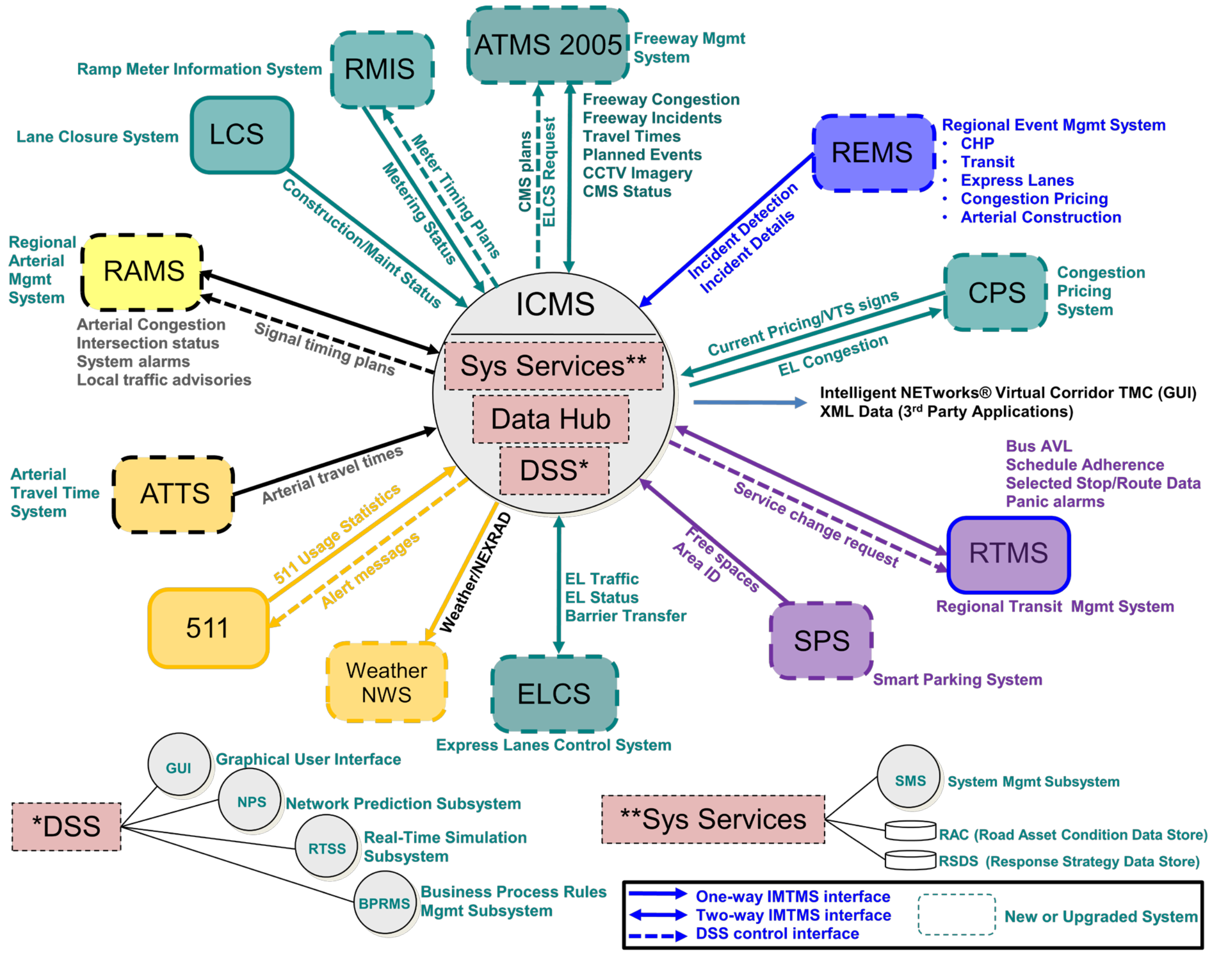

Figure 1-2. Context of San Diego ICM System Data Inputs and Outputs

It is expected that the various San Diego ICM system capabilities and strategies will be utilized in several different contexts and timeframes. These contexts and timeframes are expected to become more definitive and elaborated as the sites proceed with the design and implementation of their systems; various scenarios have been explored that consider the use of the ICM system as a response strategy for wildfires, a crash involving hazardous materials, and heavy congestion at different locations along the corridor. Further, these uses are expected to evolve as the sites work through their six-month "shakedown" periods following the initial system go-live dates, and possibly, continuing to some extent into the 12-month post-deployment data collection period. Currently, it is expected that the ICM systems will be applied in at least the following general contexts and timeframes:

1. In "real time" (or near real time), based on congestion levels
2. In advance, e.g., pre-planned:
    a. Anticipating a specific, atypical event, such as major roadway construction or a large sporting event; and

b. Periodic or cyclical (e.g., seasonal) adjustments to approaches based on lessons learned and evolution of the ICM strategies and/or in response to lasting changes in transportation conditions either directly related to ICM strategy utilization (e.g., drivers who may have switched to transit during a specific ICM-supported traffic incident choosing to continue to use transit on a daily basis) or other, non-ICM related changes such as regional travel demand.

1.2.2 San Diego ICM Deployment Schedule

Table 1-2 presents the San Diego ICM deployment schedule. As indicated in Table 1-2, individual components of the deployment will be completed in a phased manner, with full ICM system operations currently scheduled to commence in February 2013. The San Diego site team has indicated that they do expect, to at least some degree, to begin using individual components and associated ICM strategies as they become available prior to the overall system go-live. The approach to this analysis attempts to take that phasing into consideration. Since both the completion dates of the individual ICM components and the San Diego site team's utilization of them are expected to evolve as the ICM system design, implementation and shakedown periods progress, the approach presented in this test plan may flex somewhat in response.

Table 1-2. San Diego ICM Deployment Schedule

Activity	Completion Date
Complete Planning Phase	November 2010
Design/Build Phase (complete unit testing):	
Iteration 1: Intelligent NETworks (iNET) Integrated Corridor Management System (ICMS) configuration, new datahub interfaces, Traffic Management Data Dictionary (TMDD) v3.0 conversion, error-checked real-time (R/T) Traffic model, response plan data store design	April 2012
Iteration 2: R/T traffic model with response plans, iNET updates for response plan and event management	August 2012
Iteration 3: Predictive modeling, iNET update for predictive modeling, integration of all DSS capabilities in all subsystems	January 2013
Additional field element construction	January 2013
Complete Acceptance Testing	January 2013
Operations Go Live	February 2013
Complete Shakedown Period	July 2013
Complete Evaluation One Year Operational Period	July 2014

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1.2.3 Comparison to the Dallas ICM Deployment

The overall objectives of the San Diego ICM deployment are similar to those in Dallas and many of the same general operational strategies are planned, focusing on improving the balance between travel supply and demand across multiple modes and facilities, including highways, arterial streets and transit. The major distinctions in the ICM strategies to be utilized by each site generally flow from the differences in their transportation systems:

- The San Diego corridor includes extensive bus rapid transit whereas the U.S. 75 corridor in Dallas includes the Red Line Light Rail Transit (LRT) service.
- The San Diego corridor includes concurrent flow HOT/managed lanes whereas the Dallas corridor includes HOV lanes:
  - The San Diego corridor includes a recently expanded four-lane managed lane system in the I-15 median that is variably priced high occupancy tolling and includes two reversible center lanes. The San Diego site team does not expect ICM to impact their variable pricing decisions but it will impact their use of the four configurable managed lanes.
  - The Dallas U.S.-75 corridor includes access-controlled, HOV lanes located in the median, although, like San Diego with the HOT lanes, they do not expect ICM to impact their occupancy requirement decisions.
  - Both sites currently lift HOV restrictions during major incidents.
- Both sites include major arterials that run parallel with the freeways. However, while the arterial in Dallas is continuous for the length of the corridor, there is no single continuous arterial running parallel to I-15 in San Diego; Black Mountain Road, Pomerado Road, and Centre City Parkway are parallel arterials in the I-15 corridor.
- The Dallas corridor includes an extensive frontage road system, while the San Diego I-15 corridor includes auxiliary lanes between most freeway interchanges that function similarly, though with less capacity.
- The San Diego corridor includes ramp meters on I-15 and so their traffic signal timing strategies include ramp meter signals. Dallas does not use ramp meters.
- Both sites include changes to traffic signal timing plans during heavy demand and/or incidents. The Dallas deployment includes improved traffic signal timing response plans to adjust signal timing in response to real-time traffic demands along the major parallel arterial. The San Diego deployment includes responsive traffic signal control along Black Mountain and Pomerado Roads, both of which are major arterials that parallel I-15.

1.3 National Evaluation Objectives and Process

This section summarizes key aspects of the overall ICM national evaluation. A more comprehensive discussion is contained in the National Evaluation Framework document and the details of individual analyses are documented in this and other test plans.

1.3.1 U.S. DOT Hypotheses

The U.S. DOT has established the testing of eight "hypotheses" as the primary objective and analytical thrust of the ICM demonstration phase evaluation, as shown in Table 1-3. There are a number of cause-effect relationships among the U.S. DOT hypotheses; for example, enhanced response and control is dependent on enhanced situational awareness. These relationships will be examined through the evaluation in addition to testing the individual hypotheses. Another important relationship among the hypotheses is that DSS is actually a component of enhanced response and control and, depending on the specific role played by the DSS, may also contribute to improved situational awareness.

Table 1-3. U.S. DOT ICM Evaluation Hypotheses

Hypothesis	Description
The Implementation of ICM will:	
Improve Situational Awareness	Operators will realize a more comprehensive and accurate understanding of underlying operational conditions considering all networks in the corridor.
Enhance Response and Control	Operating agencies within the corridor will improve management practices and coordinate decision-making, resulting in enhanced response and control.
Better Inform Travelers	Travelers will have actionable multimodal (highway, arterial, transit, parking, etc.) information resulting in more personally efficient mode, time of trip start, and route decisions.
Improve Corridor Performance	Optimizing networks at the corridor level will result in an improvement to multimodal corridor performance, particularly in high travel demand and/or reduced capacity periods.
Have Benefits Greater than Costs	Because ICM must compete with other potential transportation projects for scarce resources, ICM should deliver benefits that exceed the costs of implementation and operation.
The implementation of ICM will have a positive or no effect on:	
Air Quality	ICM will affect air quality through changes in Vehicle Miles Traveled (VMT), person throughput, and speed of traffic, resulting in a small positive or no change in air quality measures relative to improved mobility.
Safety	ICM implementation will not adversely affect overall safety outcomes, and better incident management may reduce the occurrence of secondary crashes.
Decision Support Systems*	Decision support systems provide a useful and effective tool for ICM project managers through its ability to improve situational awareness, enhance response and control mechanisms and provide better information to travelers, resulting in at least part of the overall improvement in corridor performance.

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* For the purposes of this hypothesis, the U.S. DOT considers DSS functionality to include both those carried out by what the sites have labeled their "DSS" as well as some related functions carried out by other portions of the sites' ICM systems.

1.3.2 Evaluation Analyses

The investigation of the eight U.S. DOT evaluation hypotheses have been organized into seven evaluation "analyses," shown in Table 1-4, which generally correlate with the hypotheses. A separate analysis investigates institutional and organizational issues, which relate to all of the hypotheses since the ability to achieve any intended ICM benefits depends upon successful institutional coordination and cooperation.

Table 1-4. Relationship Between U.S. DOT Hypotheses and Evaluation Analyses

U.S.DOT Hypotheses	Evaluation Analysis Area
• Improve Situational Awareness • Enhance Response and Control	Technical Assessment of Operator Capability to Monitor, Control, and Report on the Status of the Corridor
• Better Inform Travelers	Traveler Response (also relates to Enhance Response and Control)
• Improve Corridor Performance	Quantitative Analysis of the Corridor Performance – Mobility
• Positive or No Impact on Safety	Quantitative Analysis of the Corridor Performance – Safety
• Positive or No Impact on Air Quality	Air Quality Analysis
• Have Benefits Greater than Costs	Benefit-Cost Analysis
• Provide a Useful and Effective Tool for ICM Project Managers	Evaluation of Decision Support Systems

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The evaluation features a "logic model" approach in which each link in the cause-effect sequence necessary to produce the desired impacts on transportation system performance is investigated and documented, beginning with the investments made ("inputs"), the capabilities acquired and their utilization ("outputs") and traveler and system impacts ("outcomes").

Collectively, the results of the eight evaluation analyses will provide a comprehensive understanding of the ICM demonstration phase experience:

- What ICM program-funded and other key ICM-supporting investments did the Dallas and San Diego site teams make, including hardware, software, and personnel (inputs)?
- What capabilities were realized through those investments; how were they exercised and to what extent did they enhance previous capabilities (outputs)?
- What were the impacts of the ICM deployments on travelers, transportation system performance, safety and air quality (outcomes)?
- What institutional and organizational factors explain the successes and shortcomings associated with implementation, operation and effectiveness (inputs, outputs and outcomes) of ICM and what are the implications for U.S. DOT policy and programs and for transportation agencies around the country (Institutional and Organizational Analysis)?

- How well did the DSS perform (DSS Analysis)?
- What is the overall value of the ICM deployment in terms of benefits versus costs (Benefit-Cost Analysis)?

1.3.3 Evaluation Process and Timeline

Figure 1-3 shows the anticipated sequence of evaluation activities. The evaluation will collect 12 months of baseline (pre-ICM deployment) data and, following a 6-month shakedown period, 12 months of post-deployment data.

The major products of the evaluation are two interim technical memoranda after the end of the baseline and post-deployment data collection efforts and a single final report documenting the findings at both sites as well as cross-cutting results. Two formal site visits are planned by the national evaluation team to each site: as part of evaluation planning during national evaluation framework development and test planning-related visits. Additional data collection trips will be made by various members of the national evaluation team during baseline and post-deployment data collection.

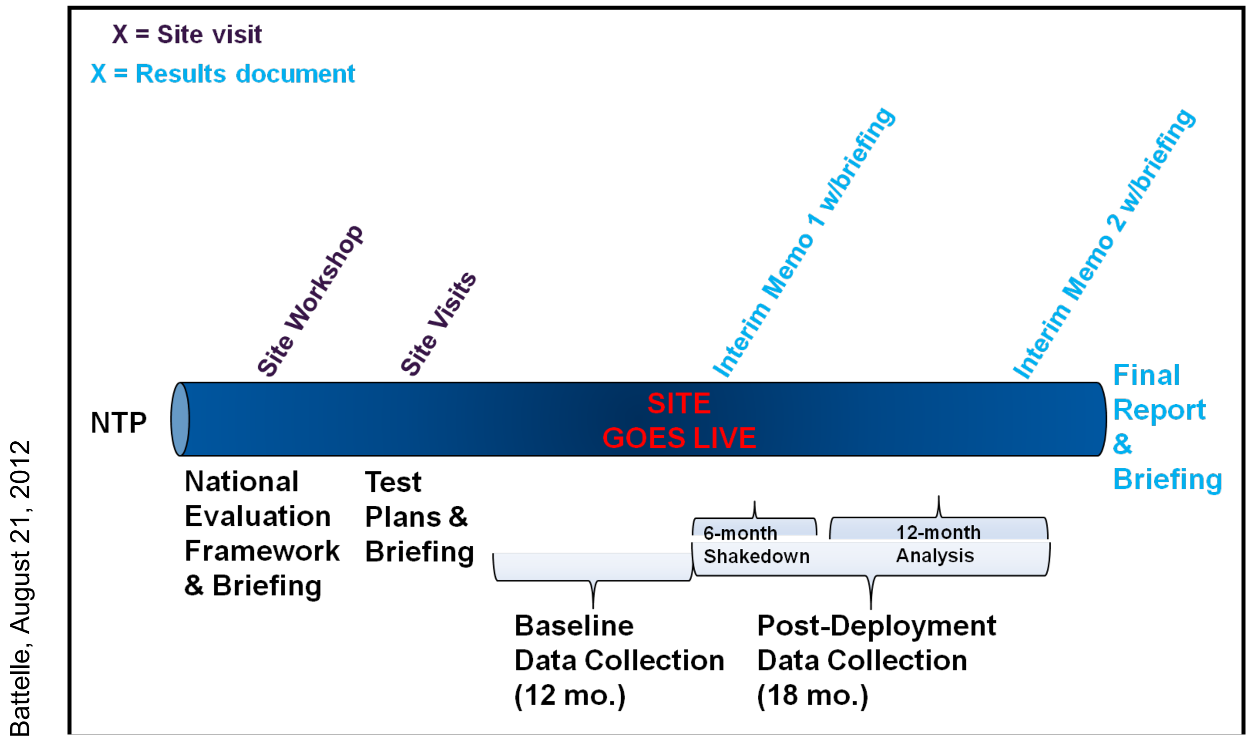

Figure 1-3. Sequence of Evaluation Activities

Based on current deployment schedules for both Dallas and San Diego, the anticipated schedule for major evaluation activities in San Diego is as follows:

- Finalize test plans – Summer 2012
- Collect baseline (pre-ICM deployment) data – Winter 2012 through Winter 2013
- Complete Interim Technical Memorandum on baseline data – Spring 2013
- Collect post-deployment data – Winter 2013 – Summer 2014
- Complete Interim Technical Memorandum on evaluation results – Fall 2014
- Complete Final Report – Spring 2015

1.3.4 Roles and Responsibilities

The U.S. DOT ICM Management Team is directing the evaluation and is supported by the Volpe National Transportation Systems Center (Volpe Center), Noblis and ITS America. The national evaluation team is responsible for leading the evaluation consistent with U.S. DOT direction and is responsible for collecting certain types of evaluation data—namely partnership documents and conducting workshops and interviews. The national evaluation team is also responsible for analyzing all evaluation data—including that collected by the national evaluation team as well as the Volpe Center and the San Diego site team—preparing reports and presentations documenting the evaluation results, and archiving evaluation data and analysis tools in a data repository that will be available to other researchers. The San Diego site team is responsible for providing input to the evaluation planning activities and for collecting and transmitting to the national evaluation team most of the evaluation data not collected directly by the national evaluation team. The national evaluation team will create and disseminate surveys to the San Diego site team, who will assist and coordinate with logistics. The Volpe Center is providing technical input to the evaluation and will carry out the traveler survey activities discussed in the Traveler Response Test Plan. The U.S. DOT Analysis, Modeling and Simulation contractor, Cambridge Systematics, will provide key AMS modeling results to the evaluation, namely person-trip measures that cannot be feasibly collected in the field, and will utilize certain evaluation outputs, such as those related to traveler response, to calibrate the AMS tools post-ICM deployment.

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2.0 MOBILITY ANALYSIS

This chapter presents the proposed approach to the mobility portion of the San Diego ICM Corridor Performance Analysis. This chapter includes a summary of the overall approach, descriptions of required evaluation data elements, presentation of the analysis approach, and a discussion of risks and mitigations associated with mobility analysis data.

2.1 Analysis Overview

This section provides a high-level overview of the approach to the mobility analysis, including a discussion of evaluation hypotheses to be tested and measures of effectiveness (MOEs) and a summary of several special considerations associated with this analysis.

Figure 2-1 graphically summarizes the approach to this analysis. This analysis focuses on the U.S. DOT ICM evaluation hypothesis pertaining to how ICM-related enhancements impact corridor performance in terms of the efficient movement of travelers. Quantitative analysis of corridor mobility performance is a core component of the evaluation in that it directly measures the "bottom line" ICM objective: to provide a measurable improvement in mobility within the corridor. This analysis includes a comprehensive, before-after comparison of the impact of ICM strategies on corridor mobility performance. The key MOEs for this analysis are travel time, delay, throughput, and travel time reliability. Corridor mobility performance will be evaluated in terms of these four MOE categories at the corridor and network levels and by mode. The analysis will also evaluate the MOEs at vehicle-based and person- or trip-based levels to capture ICM's impacts on selected origin-destination (O-D) trips.

It is expected that the benefits of the ICM System are mostly realized during high-demand conditions and major capacity reduction events such as major incidents. Therefore, the national evaluation will pay special attention in analyzing the corridor mobility performance during high-demand conditions and major capacity reduction events, including major incidents and unusual conditions (i.e., severe weather, holiday and seasonal congestion, homeland security events, and planned special events) associated with varying demand levels. The national evaluation team's approach to comprehensively evaluating such conditions and events is to link and synchronize the evaluation among multiple analysis areas, including technical capability, mobility, traveler response, and decision support system. Further discussion of linking and synchronizing the evaluation effort across multiple analysis areas can be found in Section 2.4.3.

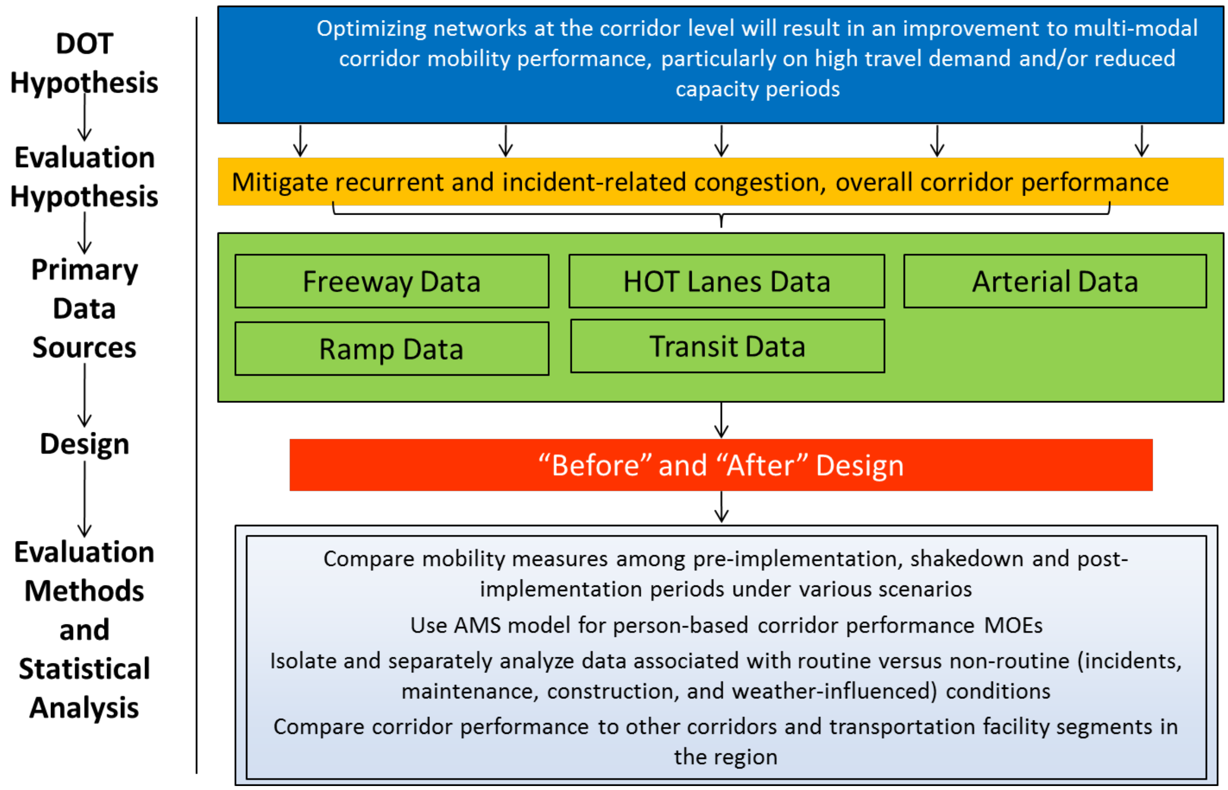


Figure 2-1. Overview of Mobility Analysis

2.1.1 Hypothesis Testing

As indicated in Figure 2-1, U.S. DOT has identified a single, broad hypothesis related to ICM mobility impacts:

> *Improve Corridor Performance: Optimizing networks at the corridor level will result in an improvement to multimodal corridor performance, particularly in high travel demand and/or reduced capacity periods.*

This analysis has disaggregated these high-level hypotheses into a series of more discrete, measurable hypotheses that can be individually tested and examined. These evaluation hypotheses are grouped into two categories: those that reference the overall, synergistic impacts of the entire ICM deployment, and those that pertain to the impacts of specific ICM strategies or groups of strategies. Evaluation hypotheses in each area are as follows.

Overall ICM Mobility Hypotheses:

- The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput.
- The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability.
- The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes.

ICM Strategy-Specific Hypotheses:

- A common incident reporting system will reduce incident response time, incident clearance time and roadway clearance time, thus reducing overall incident-related delay.
- Dissemination of en-route traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput.
- Dissemination of en-route traveler information will encourage route shifts and result in increased corridor vehicle and person throughput.
- Providing pre-trip traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput.
- Providing pre-trip traveler information will encourage route shifts and result in increased corridor vehicle and person throughput.
- Coordination of traffic signals (including coordination between adjacent ramp signals) will reduce overall delay, improve travel time and travel time reliability and increase throughput.
- Implementation of incident timing plans during incidents will reduce overall delay and improve travel time, throughput, and travel time reliability.
- Opening HOV lanes for all traffic during major incidents will reduce overall corridor travel time and delay and improve throughput.

Table 2-1 identifies the specific data and MOEs that will be used to test the various evaluation hypotheses. The particulars of each data type are elaborated in Section 2.2. The overall analytical design of this analysis is a before vs. after comparison.

Table 2-1. Mobility Analysis Data Elements, MOEs, and Hypotheses

Data Element		MOE	Hypotheses
Quantitative Data			
1. Traffic Volume	1.1 I-15 General Purpose Lane Traffic Volume	• Changes in vehicle throughput – freeway general purpose (GP) lanes • Changes in vehicle throughput – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle-miles traveled – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle hours traveled – corridor-wide and O-D pairs, by mode and direction • Support the analysis of person throughput measures (person-miles traveled and person-hours traveled) • Support the analysis of incident recovery time	• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput • Dissemination of en-route traveler information will encourage route shifts and result in increased corridor vehicle and person throughput • Providing pre-trip traveler information will encourage route shifts and result in increased corridor vehicle and person throughput
	1.2 I-15 HOT Lane Traffic Volume	• Changes in vehicle throughput – freeway HOT lanes • Changes in vehicle throughput – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle-miles traveled – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle hours traveled – corridor-wide and O-D pairs, by mode and direction • Support the analysis of person throughput measures (person-miles traveled and person-hours traveled) • Support the analysis of incident recovery time	
	1.3 Arterial Traffic Volume	• Changes in vehicle throughput – arterials • Changes in vehicle throughput – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle-miles traveled – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle hours traveled – corridor-wide and O-D pairs, by mode and direction • Support the analysis of person throughput measures (person-miles traveled and person-hours traveled) • Support the analysis of incident recovery time	

Table 2-1. Mobility Analysis Data Elements, MOEs, and Hypotheses (Continued)

<table>
<tr><th colspan="2">Data Element</th><th>MOE</th><th>Hypotheses</th></tr>
<tr><td colspan="4">Quantitative Data (Cont.)</td></tr>
<tr><td>1. Traffic Volume (Cont.)</td><td>1.4 Ramp Volume</td><td>• Changes in vehicle throughput – freeway GP lanes
• Changes in vehicle throughput – arterials/frontage roads
• Changes in vehicle throughput – corridor-wide and O-D pairs, by mode and direction
• Support the analysis of person throughput measures (person-miles traveled and person-hours traveled)
• Support the analysis of incident recovery time</td><td>• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput
• Dissemination of en-route traveler information will encourage route shifts and result in increased person throughput
• Coordination of traffic signals (including coordination between adjacent ramp signals) will reduce overall delay, improve travel time and travel time reliability and increase throughput
• Implementation of incident timing plans during incidents will reduce overall delay and improve travel time, throughput, and travel time reliability</td></tr>
<tr><td>2. Traffic Speed and Travel Time</td><td>2.1 I-15 General Purpose Lane Traffic Speed</td><td>• Changes in freeway GP lanes travel time
• Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction
• Changes in total vehicle delay – corridor-wide and O-D pairs, by mode and direction
• Changes in total vehicle delay – freeway GP lanes
• Changes in average delay per vehicle
• Changes in travel time index – corridor-wide and O-D pairs, by mode and direction
• Changes in 80th, 90th and 95th percentile travel times – corridor-wide and O-D pairs, by mode and direction
• Changes in standard deviation of travel time – corridor-wide and O-D pairs, by mode and direction
• Changes in planning time index – corridor-wide and O-D pairs, by mode and direction
• Changes in buffer index – corridor-wide and O-D pairs, by mode and direction
• Support the analysis of incident recovery time</td><td>• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability
• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes</td></tr>
</table>

Table 2-1. Mobility Analysis Data Elements, MOEs, and Hypotheses (Continued)

Data Element		MOE	Hypotheses
Quantitative Data (Cont.)			
2. Traffic Speed and Travel Time (Cont.)	2.2 I-15 HOT Lane Traffic Speed	• Changes in freeway HOT lanes travel time • Changes in total vehicle delay – freeway HOT lanes • Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction • Changes in total vehicle delay – corridor-wide and O-D pairs, by mode and direction • Changes in average delay per vehicle • Changes in travel time index – corridor-wide and O-D pairs, by mode and direction • Changes in 80th, 90th and 95th percentile travel times – corridor-wide and O-D pairs, by mode and direction • Changes in standard deviation of travel time – corridor-wide and O-D pairs, by mode and direction • Changes in planning time index – corridor-wide and O-D pairs, by mode and direction • Changes in buffer index – corridor-wide and O-D pairs, by mode and direction • Support the analysis of incident recovery time	• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes • Opening HOV lanes for all traffic during major incidents will reduce overall corridor travel time and delay and improve throughput

Table 2-1. Mobility Analysis Data Elements, MOEs, and Hypotheses (Continued)

<table>
<tr><th colspan="2">Data Element</th><th>MOE</th><th>Hypotheses</th></tr>
<tr><td colspan="4">Quantitative Data (Cont.)</td></tr>
<tr><td>2. Traffic Speed and Travel Time (Cont.)</td><td>2.3 Arterial Speed/ Travel Time</td><td>• Changes in arterial travel time
• Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction
• Changes in total vehicle delay – arterials, by direction
• Changes in total vehicle delay – corridor-wide and O-D pairs, by mode and direction
• Changes in average delay per vehicle
• Changes in travel time index – corridor-wide and O-D pairs, by mode and direction
• Changes in 80th, 90th and 95th percentile travel times – corridor-wide and O-D pairs, by mode and direction
• Changes in standard deviation of travel time – corridor-wide and O-D pairs, by mode and direction
• Changes in planning time index – corridor-wide and O-D pairs, by mode and direction
• Changes in buffer index – corridor-wide and O-D pairs, by mode and direction
• Support the analysis of incident recovery time</td><td>• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability
• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes</td></tr>
<tr><td rowspan="2">3. Roadway Geometry</td><td>3.1 I-15 Geometry (number of lanes by segment, distance between ramps, and detector locations)</td><td>• Changes in vehicle and person throughput – freeway GP lanes
• Changes in vehicle and person throughput – corridor-wide and O-D pairs, by mode and direction</td><td rowspan="2">• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability
• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes
• Coordination of traffic signals (including coordination between adjacent ramp signals) will reduce overall delay, improve travel time and travel time reliability and increase throughput
• Implementation of incident timing plans during incidents will reduce overall delay and improve travel time and throughput</td></tr>
<tr><td>3.2 Arterials Geometry (number of lanes by link and link lengths)</td><td>• Changes in vehicle and person throughput – arterials, by direction
• Changes in vehicle and person throughput – corridor-wide and O-D pairs, by mode and direction</td></tr>
</table>

Table 2-1. Mobility Analysis Data Elements, MOEs, and Hypotheses (Continued)

Data Element		MOE	Hypotheses
Quantitative Data (Cont.)			
4. Vehicle Occupancy Rate (i.e., average number of people per vehicle)	4.1 Average Vehicle Occupancy	• No direct linkage to a specific MOE; rather, support the analysis of person throughput MOEs	• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes
	4.2 Vehicle Occupancy in HOT Lanes	• No direct linkage to a specific MOE; rather, support the analysis of HOT lanes, O-D pairs, and corridor-wide person throughput	• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes

Table 2-1. Mobility Analysis Data Elements, MOEs, and Hypotheses (Continued)

Data Element		MOE	Hypotheses
Quantitative Data (Cont.)			
5. HOV/HOT Violation Rate	5.1 HOV/HOT Violation Rate	• No direct linkage to a specific MOE; rather, support the analysis of HOT lanes and corridor-wide vehicle and person throughput	• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes
6. Transit Data	6.1 Transit Passenger Count	• Changes in transit passenger delay • Changes in transit ridership • Changes in transit person throughput • Changes in incident/event-related throughput	• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes • Dissemination of en-route traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput • Providing pre-trip traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput
	6.2 Transit automatic vehicle location (AVL) Data	• Changes in transit travel time • Changes in transit vehicle delay • Changes in transit passenger delay • Changes in transit on-time performance	
	6.3 Transit Schedule and Adherence	• Changes in transit vehicle delay • Changes in transit passenger delay • Changes in transit on-time performance	

Table 2-1. Mobility Analysis Data Elements, MOEs, and Hypotheses (Continued)

<table>
<tr><th colspan="2">Data Element</th><th>MOE</th><th>Hypotheses</th></tr>
<tr><td colspan="4">Quantitative Data (Cont.)</td></tr>
<tr><td rowspan="2">7. Maintenance and Construction Activities</td><td>7.1 Log of Maintenance Activities</td><td rowspan="2">No direct linkage to a specific MOE; rather, support the analysis of the following MOEs.
• Changes in vehicle throughput (including vehicle-miles and vehicle-hours traveled) – corridor-wide and O-D pairs, by mode and direction
• Changes in person throughput (including person-miles and person-hours traveled) – corridor-wide and O-D pairs, by mode and direction
• Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction
• Changes in total vehicle delay – corridor-wide and O-D pairs, by mode and direction
• Changes in average delay per vehicle
• Changes in travel time reliability (travel time index, 80th, 90th and 95th percentile travel times, standard deviation, planning time index and buffer index) – corridor-wide and O-D pairs, by mode and direction</td><td rowspan="2">• Dissemination of en-route traveler information will encourage modal shift and contribute to increased transit ridership and improved corridor person throughput
• Providing pre-trip traveler information will encourage modal shifts contribute to increased transit ridership and improved corridor person throughput</td></tr>
<tr><td>7.2 Log of Construction Activities</td></tr>
<tr><td rowspan="3">8. Events – Incidents, weather Events, and Special Events</td><td>8.1 Incident Records</td><td rowspan="3">• Changes in incident/event-related travel time, delay, throughput and travel time reliability
• Support the analysis of incident recovery time</td><td rowspan="3">• A common incident reporting system will reduce incident response time, incident clearance time and roadway clearance time, thus reducing overall incident-related delay
• Dissemination of en-route traveler information will encourage route shifts and result in increased person throughput
• Providing pre-trip traveler information will encourage route shifts result in increased person throughput
• Implementation of incident timing plans during incidents will reduce overall delay and improve travel time and throughput
• Opening HOV lanes for all traffic during major incidents will reduce overall corridor travel time and delay and improve throughput</td></tr>
<tr><td>8.2 Weather Information Records</td></tr>
<tr><td>8.3 Log of Special Events</td></tr>
</table>

Table 2-1. Mobility Analysis Data Elements, MOEs, and Hypotheses (Continued)

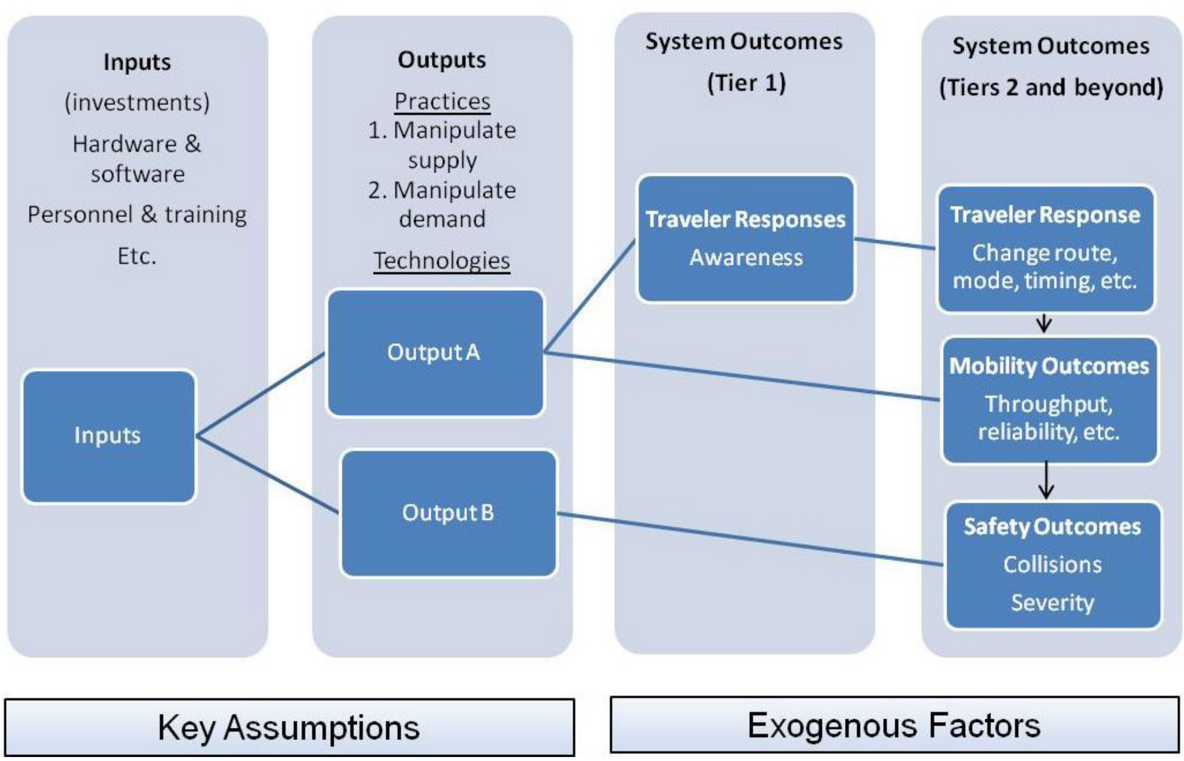
Data Element		MOE	Hypotheses
Quantitative Data (Cont.)			
9. AMS Data	9.1 Vehicle Volume and/or Throughput for Arterials-Corridor 9.2 Person Throughput for Arterials–Corridor 9.3 Vehicle Volume and/or Throughput for Arterials– O D Trips 9.4 Person Throughput for Arterials–O D Trips	• Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle and person throughput – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle- and person-miles traveled – corridor-wide and O-D pairs, by mode and direction • Changes in vehicle- and person-hours traveled – corridor-wide and O-D pairs, by mode and direction	• The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput • The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes
10. Traffic Data from other Freeway Corridors	10.1 Traffic Volume on other Freeway Corridors	• No direct linkage to a specific MOE; rather, allows for control of exogenous factors	• For control and evaluation of exogenous factors
	10.2 Traffic Speed / Travel Time on other Freeway Corridors	• No direct linkage to a specific MOE; rather, allows for control of exogenous factors	• For control and evaluation of exogenous factors
11. Ridership Data of Transit Service Outside of the Corridor	11.1 Ridership Data on other bus rapid transit (BRT), Express bus or commuter rail lines where applicable via the Data Hub	• No direct linkage to a specific MOE; rather, allows for control of exogenous factors	• For control and evaluation of exogenous factors
12. Event Case Studies	12.1 Occurrence of Candidate Event Case Studies	• No direct linkage to a specific MOE; rather, allows the analysis of many MOEs	• No direct linkage to a specific hypothesis; supports analysis related to many hypotheses
Qualitative Data			
This analysis utilizes no qualitative data			

Battelle

2.1.2 Mobility Evaluation MOEs and the Logic Model

As noted in section 1.3.2, the ICM evaluation utilizes the "Logic Model" construct for categorizing various evaluation measures of effectiveness and understanding the causal (and typically sequential) relationships among those measures. The logic model categorizes impact MOEs as either "outputs" or "outcomes." Outputs are what the ICM investments ("inputs") generate directly—such as traffic data generated by a new sensor—or which are generated by the system operators using the ICM investments, such as more coordinated responses to incidents or congestion. Outcomes describe the impact of the ICM investments (and the outputs generated by and through those investments) on travelers, the transportation system, and the environment.

In the same way that outcomes are dependent upon preceding investments and outputs, there are causal relationships or dependencies among outcomes. For example, as symbolized by the "tiers" in Figure 2-2, although some transportation system impacts such as mobility or safety may be influenced directly by outputs (e.g., changes in traffic signal timing plans) many of them many are at least partially dependent on traveler responses to the ICM system and system operators' actions (inputs and outputs). Finally, as shown in Figure 2-2, there are causal, sequential relationships within the outcome category of "traveler response." That is, changes in traveler behavior based on enhanced ICM traveler information are dependent on the travelers first being aware of the traveler information. In the larger sense, these are still "outcomes"—travelers' awareness and consultation of ICM-enhanced traveler information is certainly an outcome of the ICM system operators' generation and dissemination of that information (outputs)—but within the traveler response tier awareness and use can be seen as a necessary precedents to changes in traveler behavior based on the enhanced traveler information.



Battelle, August 21, 2012

Figure 2-2. The Evaluation Logic Model

The various traveler response MOEs presented in Table 2-1 and used in this Mobility Analysis are all, strictly speaking, outcome MOEs. Most output MOEs are captured in the Technical Capability Analysis.

2.1.3 Special Considerations

2.1.3.1 Phased Implementation of ICM Projects

As indicated in Table 1-3, individual San Diego ICM projects and the ICM strategy elements they enable are expected to be phased in over the course of what has been envisioned as the 12-month baseline data collection period—the year leading up to the go-live for the completely, fully-integrated ICM system. The overall evaluation approach for contending with the phase-in of ICM projects and strategies is to utilize available historic data (greater than 12 months before the full ICM implementation) as the baseline period in those cases where ICM projects and/or associated strategies are implemented so early within the baseline year so as to leave an insufficient quantity of "clean" (unaffected by any ICM project or strategy) baseline data, i.e., less than three or four months worth. Historic data is also useful—aside from early project deployment-related applications—as a means to understand the general trends in key MOEs like traffic volumes and transit ridership and it will be used in the evaluation for those purposes as well. Further discussion of the use of historic data, both as a way to get a "clean" baseline for ICM projects implemented early in the baseline period and as a means to understand general trends, is included in Section 2.4.

As ICM projects are phased in and as ICM strategies are employed, it will be very important for the San Diego site team to keep the national evaluation team informed. This will depend largely on the national evaluation team participation in the San Diego site team's coordination calls. This information will be carefully charted by the national evaluation team and ultimately overlaid on the collected evaluation data time series. This will allow the evaluation to attempt to identify:

- The impact of individual ICM projects and associated strategies as they come on line (this will be aided by a number of other types of data, including traveler survey data, as discussed in Section 2.4.4).
- Differences between "partial ICM implementation" conditions versus "no ICM" conditions.
- Differences between "partial ICM implementation" conditions and "full ICM" conditions.
- Differences between "full ICM" implementation conditions and "no ICM implementation."

For some MOEs, such as arterial street travel times, it is expected that no comprehensive historic data will be available. If, as is currently expected, ICM projects and associated strategies are implemented early in the baseline year that will impact such that MOE, the evaluation will by necessity focus strictly on a comparison of the baseline year conditions ("tainted" though they may be in regard to certain projects and associated impacts) with post-full ICM deployment conditions. This is consistent with the notion that the "after" or "with ICM" condition is truly defined by implementation and operation of the entire, fully-integrated ICM system rather than by when the first, separate ICM-enabling or –related project is implemented. Thus, when necessary, the baseline year—impacted as some evaluation MOEs may be by "early-deployed" ICM projects and strategies—can still serve meaningfully as the "pre-ICM" condition.

Overall, the key will be for the national evaluation team to be as fully informed as possible as projects are implemented and strategies utilized, to annotate the evaluation data time series with that information, and to place evaluation conclusions into a context in which the influence of any uncertainties or assumptions are identified.

2.1.3.2 Prompt Identification of Specific Event Case Studies

As elaborated in Sections 2.2.11 and 2.4.3, the mobility analysis features examination of a limited number of specific "event case studies:" major incidents, minor incidents, severe weather events, and planned special events. Some of these same, specific events will be analyzed in other evaluation analyses and some of those analyses will entail ad hoc data collection that will need to be initiated within a couple of days of the occurrence of the event, notably the "pulse" traveler surveys planned by the Volpe Center. Therefore, it will be important for the San Diego site team to notify the national evaluation team within 72 hours if possible when any events occur that represent candidate national evaluation event case studies. Working with the Volpe travel survey team, the national evaluation team will define a list of defining characteristics or profiles for the type of events of interest to the evaluation. This watch list will be prepared prior to the beginning of the baseline data collection year.

2.2 Quantitative Data

This section identifies the quantitative data elements to be used in the mobility portion of the Corridor Performance Analysis. Table 2-2 summarizes the data requirements for the mobility portion of the Corridor Performance Analysis. The details associated with the source, timing, and other aspects of each data element are discussed in the sections that follow. It should be noted that the "Data Collection Responsible Party" column in Table 2-2 represents the party and/or party's system/tool that generate the data.

The "start" dates for data collection in Table 2-2 generally note the start of the one-year baseline data collection period. As discussed in Section 2.1.2.1, available historic data will also be collected. That data will provide a sense of the overall, longer-term trends in key MOEs such as traffic volumes and transit ridership and, if necessary, provide a clean "pre-ICM" condition for certain MOE analyses in those cases where ICM projects and associated strategies are implemented very early in the baseline period—the 12 months preceding the overall ICM system go-live.

Table 2-2. Quantitative Data Summary

Data Element	Location Start	Location End	Data Collection Frequency	Data Collection Period[3] Start	Data Collection Period[3] End	Data Collection Responsible Party	Data Transmittal
1.1 I-15 GP Lane Volume	I-15 @ SR 78	I-15 @ SR 52	5-min	Feb 2012	July 2014	ICMS Data Hub	Continuous[4] (University of Maryland [UMD] Data Feed)
1.2 I-15 HOT Lane Volume	I-15 @ SR 78	I-15 @ SR 52	5-min	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
1.3 Arterial Volume	Northern boundary of corridor	Southern boundary of corridor	5-min	Feb 2012 and Historical	July 2014	ICMS Data Hub[5]	Continuous (UMD Data Feed)
1.4 Ramp Volume	I-15 @ SR 78	I-15 @ SR 52	5-min	Feb 2012 or Historical	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
2.1 I-15 GP Lane Speed	I-15 @ SR 78	I-15 @ SR 52	5-min	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
2.2 I-15 HOT Lane Speed	I-15 @ SR 78	I-15 @ SR 52	5-min	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
2.3 Arterial Speed / Travel Time	Northern boundary of corridor	Southern boundary of corridor	5-min	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
3.1 I-15 Geometry (number of lanes by segment, distance between ramps, and detector locations)	I-15 @ SR 78	I-15 @ SR 52	N/A	N/A	N/A	San Diego Site Team	Received (AMS Contractor provided)
3.2 Arterials Geometry (number of lanes by link and link lengths)	Northern boundary of corridor	Southern boundary of corridor	N/A	N/A	N/A	San Diego Site Team	Received (AMS Contractor provided)

[3] Data will be collected from the start of the pre-deployment and through the entirety of the post-deployment period, including the six months of "shakedown" period data (February-July 2013). The purpose of collecting the shakedown period data is to verify data collection, transmittal and archival processes; it is not expected that the shakedown data will be formally evaluated.

[4] It has been agreed with the San Diego site team that UMD—a member of the national evaluation team—will receive a direct feed to the ICMS Data Hub and PeMS. This data will be available to the entire evaluation team from UMD.

[5] Available arterial traffic stream data in the ICMS Data Hub is expected to change over the course of the baseline. Other sources of arterial data will also be made available to the evaluation team especially to characterize baseline conditions

Table 2-2. Quantitative Data Summary (Continued)

Data Element	Location		Data Collection Frequency	Data Collection Period[3]		Data Collection Responsible Party	Data Transmittal
	Start	End		Start	End		
4.1 Average Vehicle Occupancy	N/A	N/A	N/A	N/A	N/A	SANDAG	Feb 2012 and when an update is available (Alex Estrella to provide to URS)
4.2 Vehicle Occupancy in HOT Lanes	I-15 @ SR 78	I-15 @ SR 163	Monthly	Feb 2012	July 2014	Caltrans	Monthly (Caltrans to provide to URS)
5.1 HOT Violation Rate	I-15 @ SR 78	I-15 @ SR 163	Historical Data	N/A	N/A	N/A	Feb 2012 and when an update is available (Alex Estrella to provide to URS)
6.1 Transit Passenger Count	Northern boundary of corridor	Southern boundary of corridor	By station and route, and for each time a transit vehicle stops at a station	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
6.2 Transit AVL Data	Northern boundary of corridor	Southern boundary of corridor	1-min, for each vehicle	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
6.3 Transit Schedule and Adherence	Northern boundary of corridor	Southern boundary of corridor	By run	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
7.1 Log of Maintenance Activities	Northern boundary of corridor	Southern boundary of corridor	Daily	Feb 2012	July 2014	ICMS Data Hub [6]	Daily (UMD Data Feed)
7.2 Log of Construction Activities	Northern boundary of corridor	Southern boundary of corridor	Daily	Feb 2012	July 2014	All agencies within the corridor[7]	Daily (UMD Data Feed)

[6] Maintenance, construction and incident data for arterials will be gathered via email records from the Cities. They are not expected to be a part of the data feed. Caltrans Interstate information will be part of the data feed and will be collected through the data feed.

[7] See previous footnote.

Table 2-2. Quantitative Data Summary (Continued)

Data Element	Location		Data Collection Frequency	Data Collection Period[3]		Data Collection Responsible Party	Data Transmittal
	Start	End		Start	End		
8.1 Incident Records	Northern boundary of corridor	Southern boundary of corridor	By incident	Feb 2012	July 2014	ICMS Data Hub[8]	Continuous (UMD Data Feed)
8.2 Weather Information Records	Northern boundary of corridor	Southern boundary of corridor	Daily, and hourly during severe weather events	Feb 2012	July 2014	San Diego Site Team and National Evaluation Team	Monthly (Email to National Evaluation Team; National Evaluation Team from National Weather Service Reports))
8.3 Log of Special Events	Within the region	Within the region	By event	Feb 2012	July 2014	San Diego Site Team	Monthly (San Diego Site Team to provide to National Evaluation Team)
9.1 AMS Data (see specifics in Section 2.2.8)	Northern boundary of corridor	Southern boundary of corridor	Hourly during selected scenarios	Feb 2012	July 2014	San Diego Site Team and AMS Contractor	As needed (AMS Contractor to provide to National Evaluation Team)
10.1 Traffic Volume on other Freeway Corridors – Interstate 5 (I-5), Interstate 805 (I-805) & Interstate 8 (I-8)	SR 78	SR 52	5-min	Feb 2012	July 2014	ICMS Data Hub	Monthly (UMD Data Feed)
10.2 Traffic Speed / Travel Time on other Freeway Corridors – I-5, I-805 & I-8	SR 78	SR 52	5-min	Feb 2012	July 2014	ICMS Data Hub	Monthly (UMD Data Feed)

[8] See previous footnote. CHP incidents are the only incidents expected to be available through the data feed.

Table 2-2. Quantitative Data Summary (Continued)

Data Element	Location		Data Collection Frequency	Data Collection Period[3]		Data Collection Responsible Party	Data Transmittal
	Start	End		Start	End		
11.1 Ridership Data of Transit Services outside of the Corridor	N/A	N/A	Daily by route	Feb 2012	July 2014	SANDAG and ICMS Data Hub, where applicable	Monthly (SANDAG to provide to National Evaluation Team and UMD Data Feed)
12.1 Occurrence of Candidate Event Case Studies	Northern boundary of corridor	Southern boundary of corridor	As they occur	Feb 2012	July 2014	Caltrans	Within 72 hours of Event (E-mail to National Evaluation Team)

Battelle

2.2.1 Traffic Volume, Speed and Travel Time

Traffic volumes and speeds will be collected using the detection systems on roadways within the corridor. Traffic volumes on I-15 general purpose and HOT lanes are collected by California Department of Transportation (Caltrans) detector stations. Caltrans' detectors provide good coverage on the I-15 segments to be analyzed. Traffic data is collected in real time by each detector on a lane-by-lane basis. Data for all lanes is then aggregated and reported in five minute intervals. In addition to volume, these detectors also measure speed and lane occupancy. Traffic data will be provided to the national evaluation team via a continuous data feed (housed at the University of Maryland [UMD]) from the ICMS Data Hub. Caltrans also stores all data collected via detectors in Caltrans Performance Measurement System (PeMS), and such data is available for the national evaluation team to download. Figure 2-3 illustrates a sample of 5-minute aggregated detector data from PeMS. The data shown in Figure 2-3 were collected at the detector station at Bernardo Center Drive on I-15 general purpose lane from 5:00 a.m. to 10:00 a.m. on March 1, 2012.

An automated traffic detection system on arterials is currently being supplemented by additional detection stations in San Diego. The system is capable of collecting volume, speed and occupancy data. Figure 2-4 presents the arterial detection coverage for the I-15 Corridor. Upon completion of installation, data collected by the arterial detectors will be made available to the national evaluation team via a continuous feed from the ICMS Data Hub. Data will also be stored in the Arterial-PeMS (A-PeMS) and allow the national evaluation team to access via the feed. SANDAG will provide baseline information on arterials through a separate channel. Two main types/sources of baseline arterial traffic data will be provided.

- Access to archived arterial data collected through the existing Sensys network stations
- Access to the various arterial data collection activities conducted for system demonstration

All ramps along the corridor are installed with detectors. Ramp volumes will be provided to the national evaluation team via a continuous feed from the ICMS Data Hub. Ramp volumes will also be available in PeMS for the national evaluation team to access.

2.2.2 Roadway Geometry

The length and number of lanes for each link or segment of the roadway are necessary to compute the total volume, average speed, and subsequently travel time, delay, throughput and travel time reliability. In addition, the locations of traffic detectors and on- and off-ramps are equally important to the Mobility Analysis. The national evaluation team has obtained the roadway geometry information from the AMS Contractor. The national evaluation team, if necessary, will inform the San Diego site team and the U.S. DOT of any additional data needs and collaborate with all involving parties to identify data availability, sources, and methods to obtain the data.

5 Minutes	Lane 1 Flow (Veh/5 Minutes)	Lane 1 Speed (mph)	Lane 2 Flow (Veh/5 Minutes)	Lane 2 Speed (mph)	Lane 3 Flow (Veh/5 Minutes)	Lane 3 Speed (mph)	Lane 4 Flow (Veh/5 Minutes)	Lane 4 Speed (mph)	Lane 5 Flow (Veh/5 Minutes)	Lane 5 Speed (mph)	Flow (Veh/5 Minutes)	Speed (mph)	# Lane Points	% Observed
3/1/2012 5:00	59.0	76.1	69.0	75.4	47.0	72.5	40.0	73.8	30.0	74.5	245.0	74.6	5	100
3/1/2012 5:05	68.0	76.3	78.0	74.4	47.0	71.0	32.0	70.3	20.0	73.0	245.0	73.6	5	100
3/1/2012 5:10	72.0	75.5	69.0	72.9	57.0	72.0	43.0	75.1	34.0	74.5	275.0	73.9	5	100
3/1/2012 5:15	114.0	75.1	91.0	73.2	61.0	68.9	50.0	74.6	28.0	71.4	344.0	73.1	5	100
3/1/2012 5:20	114.0	74.6	93.0	72.2	73.0	72.4	59.0	76.5	50.0	69.2	389.0	73.2	5	100
3/1/2012 5:25	126.0	73.5	121.0	71.5	82.0	74.1	66.0	74.4	54.0	67.2	449.0	72.4	5	100
3/1/2012 5:30	116.0	72.8	110.0	71.7	91.0	71.3	60.0	71.1	55.0	65.4	432.0	71.0	5	100
3/1/2012 5:35	144.0	72.6	121.0	72.0	87.0	70.1	76.0	67.3	61.0	61.5	489.0	69.8	5	100
3/1/2012 5:40	164.0	73.1	132.0	72.7	99.0	73.5	77.0	66.4	77.0	62.1	549.0	70.6	5	100
3/1/2012 5:45	171.0	73.7	128.0	72.5	97.0	74.6	78.0	78.6	74.0	64.5	548.0	73.0	5	100
3/1/2012 5:50	172.0	71.9	151.0	73.4	93.0	75.3	80.0	70.7	77.0	63.9	573.0	71.6	5	100
3/1/2012 5:55	166.0	71.3	126.0	71.7	95.0	68.9	70.0	63.5	68.0	62.4	525.0	68.8	5	100
3/1/2012 6:00	168.0	73.0	139.0	70.0	86.0	70.7	76.0	56.3	71.0	62.1	540.0	68.1	5	100
3/1/2012 6:05	189.0	72.7	157.0	70.5	109.0	70.3	89.0	63.1	81.0	59.3	625.0	68.6	5	100
3/1/2012 6:10	176.0	72.6	142.0	70.2	106.0	68.0	84.0	64.6	63.0	58.9	571.0	68.5	5	100
3/1/2012 6:15	212.0	72.5	182.0	70.0	118.0	66.9	96.0	61.1	87.0	59.0	695.0	67.6	5	100
3/1/2012 6:20	183.0	72.4	158.0	71.1	119.0	69.7	98.0	63.1	84.0	56.9	642.0	68.1	5	100
3/1/2012 6:25	198.0	69.1	162.0	68.1	124.0	71.1	116.0	67.4	114.0	56.6	714.0	66.9	5	100
3/1/2012 6:30	205.0	71.9	185.0	69.7	131.0	71.8	115.0	68.8	106.0	57.6	742.0	68.8	5	100
3/1/2012 6:35	198.0	74.4	184.0	70.9	149.0	73.4	96.0	69.7	109.0	53.9	736.0	69.7	5	100
3/1/2012 6:40	213.0	74.4	168.0	70.4	151.0	73.4	133.0	72.4	135.0	55.0	800.0	69.8	5	100
3/1/2012 6:45	196.0	74.8	171.0	70.0	142.0	72.3	133.0	73.8	118.0	53.0	760.0	69.7	5	100
3/1/2012 6:50	204.0	73.4	182.0	68.5	135.0	71.5	133.0	75.5	141.0	52.2	795.0	68.5	5	100
3/1/2012 6:55	217.0	73.0	185.0	69.0	156.0	69.6	141.0	70.7	140.0	49.3	839.0	67.1	5	100
3/1/2012 7:00	229.0	74.5	196.0	70.2	159.0	70.5	152.0	70.4	137.0	48.7	873.0	68.0	5	100
3/1/2012 7:05	210.0	72.9	204.0	68.5	148.0	68.9	140.0	63.8	155.0	45.9	857.0	64.8	5	100
3/1/2012 7:10	176.0	68.7	172.0	65.0	125.0	60.4	114.0	59.5	149.0	44.0	736.0	60.0	5	100
3/1/2012 7:15	195.0	66.1	192.0	64.0	144.0	59.8	141.0	62.0	149.0	44.2	821.0	59.8	5	100
3/1/2012 7:20	175.0	53.1	179.0	55.6	159.0	59.6	142.0	63.0	143.0	40.6	798.0	54.5	5	100
3/1/2012 7:25	179.0	56.8	164.0	57.1	126.0	55.9	134.0	58.7	148.0	36.4	751.0	53.0	5	100
3/1/2012 7:30	156.0	47.0	170.0	44.1	143.0	50.6	137.0	52.9	141.0	35.1	747.0	45.9	5	100
3/1/2012 7:35	138.0	38.0	142.0	47.2	130.0	49.9	144.0	55.5	134.0	31.7	688.0	44.6	5	100
3/1/2012 7:40	154.0	37.4	142.0	47.3	116.0	49.9	140.0	55.8	159.0	32.7	711.0	44.0	5	100
3/1/2012 7:45	157.0	41.4	142.0	51.2	125.0	53.1	129.0	58.7	142.0	32.3	695.0	46.9	5	100
3/1/2012 7:50	160.0	47.8	150.0	52.7	125.0	53.2	118.0	53.9	135.0	32.9	688.0	48.0	5	100
3/1/2012 7:55	175.0	63.7	170.0	63.0	127.0	57.9	114.0	54.8	135.0	33.9	721.0	55.5	5	100
3/1/2012 8:00	177.0	77.8	135.0	70.6	113.0	68.6	96.0	64.3	102.0	37.0	623.0	65.8	5	100
3/1/2012 8:05	165.0	83.4	146.0	74.6	111.0	72.1	108.0	63.1	105.0	38.2	635.0	68.5	5	100
3/1/2012 8:10	176.0	82.4	144.0	74.2	113.0	71.1	121.0	68.1	111.0	40.6	665.0	69.1	5	100
3/1/2012 8:15	196.0	83.7	154.0	76.1	110.0	71.9	121.0	71.1	95.0	37.6	676.0	71.3	5	100
3/1/2012 8:20	173.0	84.0	150.0	76.7	103.0	73.8	117.0	68.9	94.0	36.4	637.0	70.8	5	100
3/1/2012 8:25	161.0	85.1	153.0	77.2	108.0	73.2	101.0	67.5	102.0	37.2	625.0	70.4	5	100
3/1/2012 8:30	149.0	85.2	138.0	76.1	107.0	71.0	109.0	67.3	90.0	36.6	593.0	69.9	5	100
3/1/2012 8:35	175.0	84.5	159.0	75.8	127.0	72.1	102.0	66.5	92.0	36.9	655.0	70.5	5	100
3/1/2012 8:40	151.0	84.4	138.0	76.7	110.0	73.9	89.0	66.3	91.0	36.2	579.0	70.2	5	100
3/1/2012 8:45	151.0	84.2	143.0	77.2	105.0	72.0	115.0	66.1	100.0	37.8	614.0	69.5	5	100
3/1/2012 8:50	170.0	85.8	132.0	78.3	128.0	75.9	104.0	66.4	89.0	36.6	623.0	71.9	5	100
3/1/2012 8:55	128.0	86.5	131.0	79.7	93.0	76.3	92.0	68.8	97.0	35.6	541.0	71.0	5	100
3/1/2012 9:00	117.0	86.5	117.0	80.2	100.0	78.1	73.0	69.2	61.0	33.1	468.0	73.5	5	100
3/1/2012 9:05	143.0	86.5	132.0	79.6	93.0	76.4	98.0	67.8	87.0	31.4	553.0	71.2	5	100
3/1/2012 9:10	121.0	85.9	121.0	77.9	105.0	75.4	95.0	65.4	85.0	31.4	527.0	69.5	5	100
3/1/2012 9:15	114.0	86.5	123.0	77.8	103.0	75.1	116.0	68.8	96.0	32.2	552.0	69.3	5	100
3/1/2012 9:20	139.0	85.7	140.0	78.5	113.0	74.9	118.0	71.0	77.0	31.8	587.0	71.9	5	100
3/1/2012 9:25	127.0	85.2	127.0	78.0	95.0	73.8	97.0	65.9	75.0	29.2	521.0	69.7	5	100
3/1/2012 9:30	127.0	85.8	127.0	78.8	90.0	77.9	82.0	60.1	77.0	30.0	503.0	69.9	5	100
3/1/2012 9:35	125.0	85.7	122.0	77.9	102.0	77.3	96.0	61.9	76.0	28.7	521.0	69.5	5	100
3/1/2012 9:40	124.0	85.0	130.0	77.6	114.0	77.6	99.0	68.9	86.0	30.2	553.0	70.3	5	100
3/1/2012 9:45	124.0	85.8	128.0	78.8	94.0	75.7	94.0	68.7	76.0	30.2	516.0	70.9	5	100
3/1/2012 9:50	114.0	86.5	118.0	79.5	93.0	75.1	100.0	67.0	65.0	29.4	490.0	71.1	5	100
3/1/2012 9:55	114.0	86.5	117.0	79.2	87.0	71.6	72.0	64.7	72.0	30.0	462.0	69.6	5	100

California Department of Transportation, March 1, 2012

Figure 2-3. Sample PeMS Output of Aggregated I-15 Detector Data

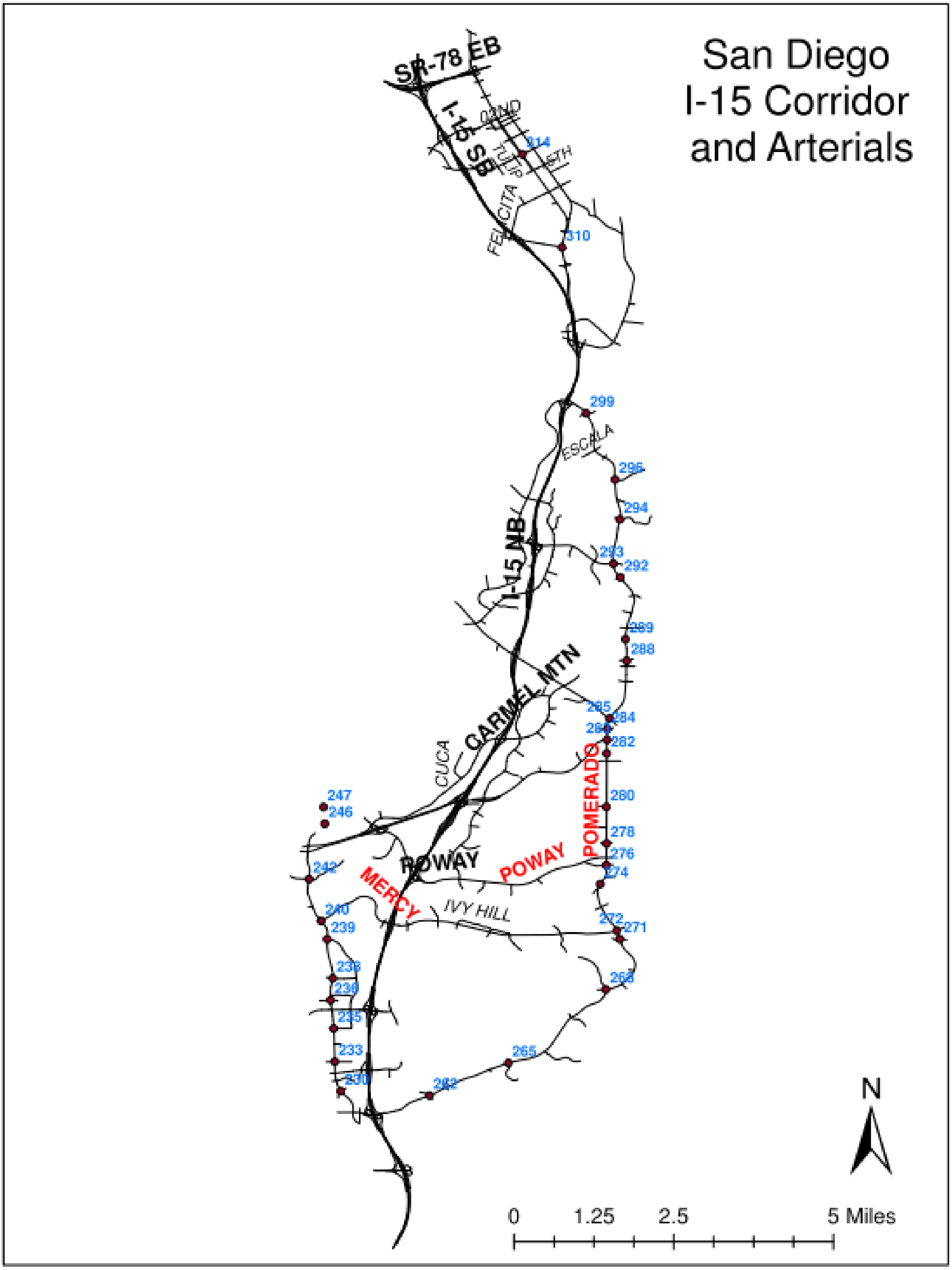


Figure 2-4. I-15 ICM Corridor Arterial Detection Coverage Map

2.2.3 Vehicle Occupancy Rate

Average vehicle occupancy rate is the average number of persons that occupy vehicles in each vehicle class of interest (e.g., automobiles, carpools, transit, etc.). For I-15 general purpose lanes and arterials, the national evaluation team will use the average vehicle occupancy (AVO) rate for automobiles for the region that is currently used in the regional transportation model. The decision to use the regional AVO rate is due to lack of a corridor-specific rate. AVO rates are traditionally estimated through labor intensive field data collection or surveys. Due to resource constraints, traditional methods for collecting and estimating AVO rate for the corridor are deemed infeasible. Using the regional AVO rate is the best available option, and based on the inputs from the San Diego site the regional AVO rate provides a valid representation for the corridor. SANDAG will provide the AVO rate to the national evaluation team. If I-15 specific AVO rates are available through Caltrans, the national evaluation team would assess its suitability for use and inclusion in the evaluation as well.

Vehicle occupancy data for the I-15 HOT lanes is collected by Caltrans on a regular basis. Caltrans will provide the data to the evaluation team monthly.

The primary source for transit vehicle occupancy will be automatic passenger counters (APCs). All BRT vehicles on the I-15 ICM Corridor will be equipped with automatically collecting passenger counts. NCTD buses are all equipped with APCs, while roughly 65 percent of the MTS buses serving local routes are equipped. APC data will be collected on a continuous basis. The national evaluation team will obtain APC data via the continuous data feed from the ICMS Data Hub. APC data will also be available via the Transit-PeMS (T-PeMS).

2.2.4 HOV/HOT Violation Rate

HOV/HOT violation information on the I-15 HOT lanes is limited. Historical statistics are available and will be provided to the national evaluation team. The San Diego site team, to the extent possible, will provide such information to the national evaluation team that is readily available during the evaluation periods. Violation rates will be used to adjust person throughput measures on HOT lanes.

2.2.5 Transit Data

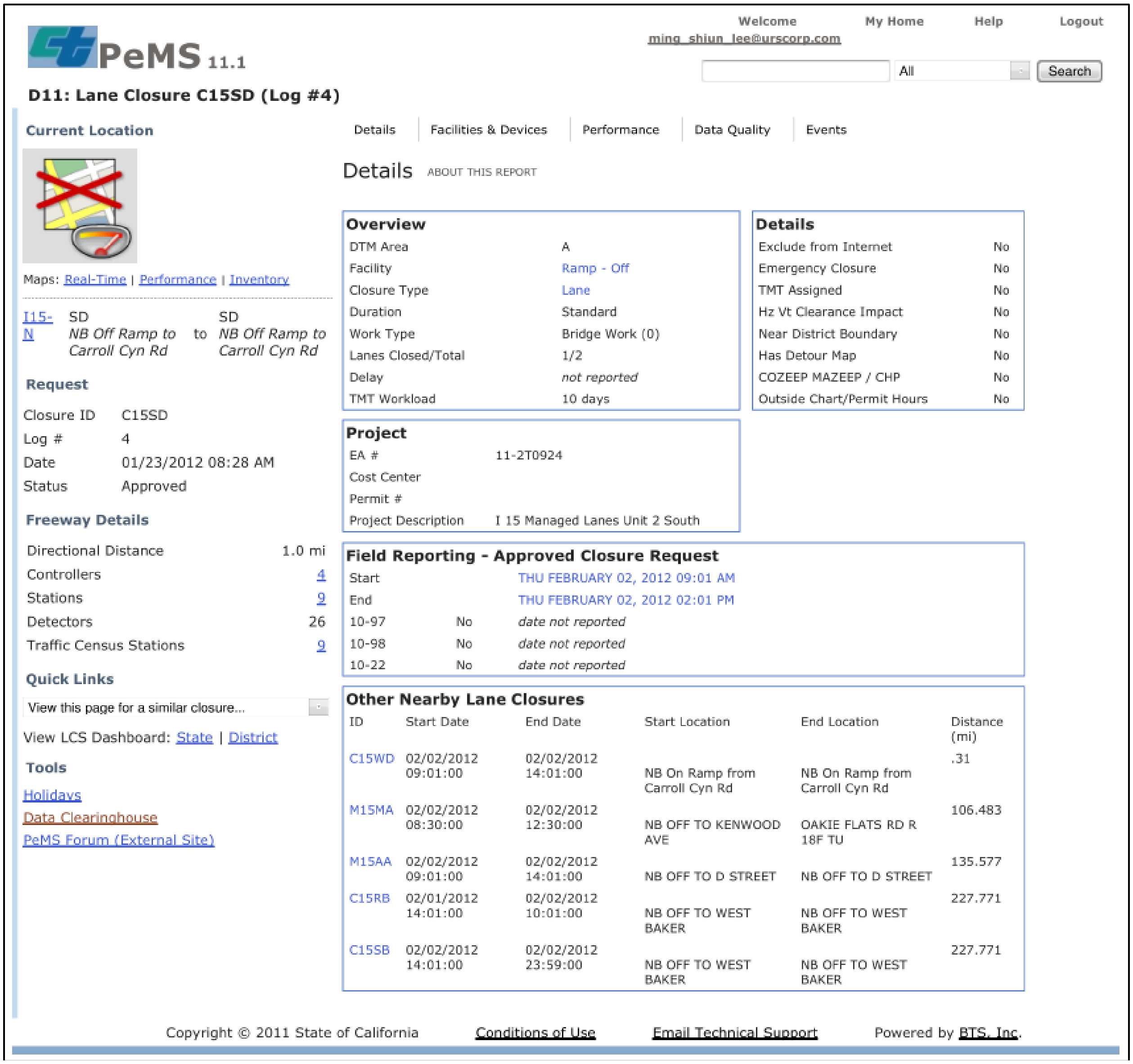
Data required from transit services includes ridership, transit vehicle locations, schedule, and on-time performance data for the BRT serving the corridor. As discussed in Section 2.2.3, BRT vehicles are equipped with APCs to collect passenger counts. Transit vehicle location data is important to determine travel time and on-time performance for the transit service. Currently, all transit vehicles are equipped with AVL. Actual transit performance based on the AVL data will be used to compare against the published schedule to determine on-time performance. Transit AVL data, schedule and on-time performance reports will be available for the national evaluation team via the ICMS Data Hub feed.

2.2.6 Maintenance and Construction Activities

For the purpose of this analysis, the national evaluation team is mostly interested in what actually took place in the field as opposed to what were scheduled to take place. The following information on actual maintenance and construction activities is needed for the evaluation:

- Date and time the activity started
- Location of the activity
- Description of the activity, e.g., replacing guard rail on right shoulder
- Duration of the activity
- Impacts on traffic, e.g., right shoulder and right lane closed
- Traffic control plans and/or diversion plans executed, if any.

Caltrans maintains a database recording current and planned maintenance and construction activities on I-15. The information will be available to the national evaluation team via the ICMS Data Hub feed. In addition, Caltrans' Lane Closure System Reports in PeMS provide information on current, recently completed, planned, and emergency closures. Figure 2-5 illustrates an example of the PeMS Lane Closure System Report.



California Department of Transportation, March 1, 2012

Figure 2-5. PeMS Lane Closure System Report Example

The San Diego site team is currently working with the local city partners to determine applicable and available maintenance and construction activity data for input to the ICM System. Availability and collection frequency for maintenance and construction activities on arterials are still being decided by the local partners but are expected to be much more limited than the freeway dataset. Where possible, the cities will maintain logs of the major maintenance and construction activities that have occurred on their facilities.

2.2.7 Events – Incidents, Severe Weather Events and Special Events

Records on traffic incidents, severe weather events, and planned special events are critical to the mobility analysis. The national evaluation team is interested in both major and minor traffic incidents. To assist with analyzing incident data to derive mobility MOEs, the following data is needed:

- Location of the incident
- Date and time of incident identification, response, and clearance
- Impacts on traffic conditions, e.g., 1 lane blocked
- ICM strategies implemented during post-deployment period.

Records for incidents on I-15 are recorded by CHP and stored in PeMS. I-15 incident records will be transmitted to the national evaluation team via the ICMS Data Hub feed. However, incidents on arterials are not currently recorded. The San Diego site team is working with partner agencies and incident responders to understand what information is available and can be made available for the evaluation. The San Diego site team is also working with partner agencies to determine a business rule and implement a process to capture and document arterial incident data. The San Diego site team will provide the data to the national evaluation team once it becomes available but these are subject to the same constraints identified for maintenance and construction information.

Heavy rain, flash flood, dense fog, and fire are the weather events that have most significant impacts on travel and roadway operations in the San Diego area. The evaluation of severe weather event scenarios will focus on these four types of weather events. The national evaluation team will track weather alerts issued by the National Weather Service. In addition to proactively observing and tracking weather events, the national evaluation team will review the data that will be obtained from the ICMS Data Hub to confirm all severe weather events are recorded. Once a weather event is identified as warranted for further investigation, the national evaluation team will gather the following information from the National Weather Service for evaluation: type of event (i.e., dense fog, heavy rain, flash flood, fire), date and time of the event, duration, event details (e.g., amount of precipitation), areas of impact, impacts and reported damages if any.

Planned special events may include but are not limited to sporting events, concerts, and community/regional festivals. Data needed for those events are date, time, duration and location of each event, areas and routes impacted, and traffic management plan implemented. The operating agencies at the San Diego Site will input information on planned special events, and those events will be logged to the ICMS. The national evaluation team will obtain planned special event data via the ICMS Data Hub feed.

2.2.8 AMS Model Results

It is not feasible to calculate person- or trip-based MOEs without a comprehensive set of field/empirical data. It appears that the data coverage for the I-15 ICM Corridor is adequate, and the national evaluation team will maximize the use of available field data to perform the analysis. However, the national evaluation team would like to obtain results from the AMS model to assist in evaluating person- or trip-based MOEs for the arterial network. AMS results will likely be used if there are data gaps on the arterial network, particularly on secondary roads that connect to principal arterials. Data needed includes arterial network volume and throughput measures for the entire corridor and for trips between a set of O-D pairs for both pre- and post-deployment periods for normal daily operations and selected scenarios including:

- Major incidents
- Minor incidents
- Severe weather events
- Planned special events

Specifically, the following AMS outputs will be required:

- Person trip O-D matrix by mode of travel
- Link- or segment-level traffic volumes by time of day

Section 2.4.3.2 describes the above scenarios and further discuss the national evaluation team's approach to evaluating them.

The national evaluation team is aware that the AMS model for the San Diego site is capable of producing acceptable results for scenarios involving major and minor incidents. The AMS model has the ability to simulate scenarios involving severe weather or planned special events, however, no such scenarios were modeled during the AMS effort. During Stage 2 AMS, the San Diego AMS model was calibrated to simulate fifteen operational conditions, represented by combinations of low, medium, and high demand conditions; under no incident and incidents on freeway or arterial; and with or without operational DSS. In Stage 3A, three alternative analysis scenarios are being developed for the purpose of assessing the performance of the proposed ICMS under different conditions. The three alternatives are[9]:

- Daily operations with corridor ramp metering
- Freeway incident with responsive signal operations
- Freeway incident under suboptimal ICM performance

The national evaluation team assumes that, in Stage 3B, recalibration and validation of the AMS model can cover similar combinations of operational conditions as it was performed in Stage 3A. The AMS model will be able to simulate weather and planned special event scenarios.

AMS model results will be provided to the national evaluation team by the AMS Contractor, Cambridge Systematics, as specified in Cambridge Systematics' scope of work for AMS Stage 3B. Modeling results for normal daily conditions will be provided to the national evaluation team during the first 6 months of the pre- and post-deployment periods. Results for selected capacity reduction events (e.g., major and minor incidents, weather and planned special events if available) will be provided by the AMS Contractor to the national evaluation team

[9] "Integrated Corridor Management, Analysis, Modeling, and Simulation for the I-15 Corridor in San Diego, California, Analysis Plan," prepared by Cambridge Systematics, Inc. for U.S. DOT, May 26, 2011.

within 2 months after receiving field data on each of those events by the national evaluation team and the San Diego site.

2.2.9 Traffic Data from Other Freeway Corridors

There are many "exogenous factors" that influence whether intended outcomes are realized and/or whether they can be measured and attributed to the ICM investment. Exogenous factors are further discussed in Section 2.4.6. Changes in travel demand and patterns in the corridor between evaluation periods are some of the exogenous factors that will have an impact on overall corridor performance. Traffic volume and speed/travel time data from other freeway corridors in the San Diego area will be used to compare against data from freeway detectors in the I-15 Corridor to determine if overall travel demand and patterns have changed significantly between the pre- and post-deployment periods.

The national evaluation team proposes to use the following corridors for the purpose of evaluating exogenous factors:

- I-5 between SR 78 and SR 52
- I-805 between I-5 (to the north) and SR 52
- I-8 between SR 67 and I-15

I-5 and I-805 are north-south corridors west of the I-15 Corridor and are instrumented with adequate roadway detectors to collect traffic volume and speed data. I-8 is the region's busiest east-west corridor. Traffic data from those corridors will be collected by Caltrans using roadway detection systems. Data will be stored and available via PeMS. The national evaluation team will obtain the data from PeMS directly.

2.2.10 Ridership Data from Other Transit Routes

Similar to traffic data from other freeway corridors in the region, ridership data on other transit routes outside of the I-15 Corridor will be compared to ridership of I-15 BRT to determine if travel demand and patterns in the corridor have changed dramatically between the evaluation periods. NCTD and MTS collect ridership using APCs. While NCTD fleet is 100 percent instrumented with APCs, MTS vehicles are about 65 percent instrumented. Ridership information of the following transit routes will be collected for the purpose of ridership comparison:

- COASTER: commuter train serving between San Diego and Oceanside
- Route 50: Downtown – UTC Express
- Route 150: Downtown – UTC/VA Express
- Route 870: El Cajon TC – Kearny Mesa Express
- NCTD Route 101: Oceanside – V.A./UTC via Highway 101
- South Bay BRT: a new BRT route that may become operational during the post-ICM period
- San Diego Trolley
- North County SPRINTER: light-rail line between Oceanside and Escondido

Daily ridership data from other transit routes will be obtained from SANDAG on a monthly basis.

2.2.11 Occurrence of Candidate Event Case Studies

The San Diego site team will attempt to notify the national evaluation team within 72 hours of any events that fit the profile of the type of events identified by the national evaluation as of potential interest as an event case study. These profiles or "watch list" will be developed by the national evaluation team (based on historic incident data provided by the San Diego site team) and provided to the San Diego site team prior to the beginning of baseline data collection.

2.3 Qualitative Data

No qualitative data elements are currently required for use in mobility portion of the corridor performance analysis.

2.4 Data Analysis

This section describes how the gathered mobility performance data will be analyzed. Specifically, for each hypothesis relevant to the mobility analysis, the approach to testing the hypotheses and/or drawing conclusions is be discussed, including statistical and analytical processes and tools.

2.4.1 Hypothesis Testing

As discussed in Section 2.1, mobility-related ICM evaluation hypotheses are grouped in two categories: (1) overall ICM mobility hypotheses and (2) ICM strategy-specific hypotheses. MOEs to test those hypotheses can be categorized into the following four groups: (1) travel time, (2) delay, (3) throughput, and (4) travel time reliability. Table 2-3 below summarizes the mobility-related hypotheses, MOE(s) that will be used to test each hypothesis, and section(s) in this test plan where methods to test hypotheses can be found.

Table 2-3. **Mobility Analysis Hypotheses, MOEs and Testing Methods**

Hypothesis	MOE Category	Testing Method
Overall Mobility Hypotheses		
The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput	Throughput	Section 2.4.5.3
The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability	Travel time, Travel time reliability	Section 2.4.5.1, Section 2.4.5.4
The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes	Delay	Section 2.4.5.2
Strategy-Specific Hypotheses		
A common incident reporting system will reduce incident response time, incident clearance time and roadway clearance time, thus reducing overall incident-related delay.	Delay	Section 2.4.5.2
Dissemination of en-route traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput	Throughput	Section 2.4.5.3
Dissemination of en-route traveler information will encourage route shifts and result in increased corridor vehicle and person throughput	Throughput	Section 2.4.5.3
Providing pre-trip traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput	Throughput	Section 2.4.5.3
Providing pre-trip traveler information will encourage route shifts and result in increased corridor vehicle and person throughput	Throughput	Section 2.4.5.3
Coordination of traffic signals (including coordination between adjacent ramp signals) will reduce overall delay, improve travel time and travel time reliability and increase throughput	Travel time, Delay, Throughput, Travel time reliability	Section 2.4.5.1, Section 2.4.5.2, Section 2.4.5.3, Section 2.4.5.4
Implementation of incident timing plans during incidents will reduce overall delay and improve travel time, throughput, and travel time reliability	Travel time, Delay, Throughput	Section 2.4.5.1, Section 2.4.5.2, Section 2.4.5.3
Opening HOV lanes for all traffic during major incidents will reduce overall corridor travel time and delay and improve throughput	Travel time, Delay, Throughput	Section 2.4.5.1, Section 2.4.5.2, Section 2.4.5.3

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2.4.2 Data Aggregation

To compute the mobility performance measures, the national evaluation team will aggregate roadway detection data spatially. Detector station data will be converted to link-level data. At this level, a "zone of influence" will be assigned for each detector station. This zone of influence will be equivalent to one-half the distance to the nearest upstream and downstream detector stations. Link travel times will be computed by applying the average detector station speed over the zone of influence for each detector station. Vehicle volumes will be subtotaled and multiplied by link length to estimate vehicle miles of travel (VMT) for each link.

The link-level data will be aggregated to the segment and corridor levels. A segment is defined as a section of roadway between major interchanges/intersections/decision points. A segment may be comprised of 1 or multiple links, and the length of a segment generally ranges from 1 mile to 3 miles, depending on the distance between intersections/interchanges as well as detector spacing. For determining segment travel times, the "vehicle trajectory" approach, as opposed to the "snapshot" approach, will be used. The vehicle trajectory method of computing travel time attempts to more closely estimate the actual travel times experienced by motorists. The approach "traces" vehicles trips in time as they progress through a corridor. This is done by applying the link travel time corresponding to the precise time in which a vehicle will be using a link. For example, if it takes a vehicle two minutes to traverse a link at 7:00, then the link travel time starting at 7:02 would be used as the travel time for next downstream link. This process is continued for all the links that make up segments or corridor.

In addition to aggregating the data spatially, individual detector data will be aggregated temporally. The lowest level detector data will be aggregated to 5-minute intervals. This means that vehicle counts from detectors will be summed to provide a total number of vehicles in the 5-minute interval, while speed and occupancy data will be averaged to provide an average speed and occupancy for the 5-minute interval.

2.4.3 Typical and Atypical Conditions

Based on the results from the AMS model, it is expected that the benefits of the ICM System are mostly realized during high-demand conditions and major capacity reduction events such as major incidents. As such, in addition to daily recurring congestion conditions, the national evaluation will also focus on atypical conditions that will include incidents, severe weather events, and planned special events.

2.4.3.1 Daily Operations

For the purpose of evaluating ICM impact on corridor daily operations (i.e., recurring congestion conditions), performance measures will be computed for peak hours and peak periods.

Peak hour statistics provide an indication of corridor performance when recurring congestion is at its worst. The evaluation will use two methods to define the peak hour. The first method is the traditional method of determining the peak hour by applying the Highway Capacity Manual's definition of peak hour, which is the one-hour period experiencing the highest hourly traffic volume. The second method is by defining the one-hour period when travel speeds are at their worst. The national evaluation team will compute performance measures for both morning and afternoon peak using both definitions. Peak hours will be determined separately for the pre-and post-deployment periods based on data collected on Wednesdays during the evaluation period. That is, peak hours for the pre-deployment period will be determined using the data collected during that 12-month period, while peak hours for the post-deployment period will be derived using data from the post-deployment period. The same peak hours will be kept constant within each evaluation period.

In addition, the national evaluation team will compute peak period performance measures. For the purpose of this evaluation, morning and afternoon peak periods are defined to be from 5:30 a.m. to 9:30 a.m. and from 3:00 p.m. to 7:00 p.m., respectively. The national evaluation team will work with the San Diego site team to adjust the definitions of peak periods as appropriate.

Only data from non-holiday weekdays will be included in the daily operations analysis. Data from weekends and Federal and state holidays will be excluded from this daily operations analysis as traffic conditions on those days are not representative for daily recurring congestion conditions. Data from periods that traffic is impacted by atypical conditions will also be excluded from this analysis. Atypical conditions as defined earlier include incidents, severe weather events, planned special events, and homeland security events. The data may exhibit seasonal variations such as summer versus winter and times when schools are in and out of sessions. While the national evaluation does not envision needing to conduct separate analysis for different seasons, data will be examined to determine if significant seasonal variations exist that might influence the overall analysis.

2.4.3.2 Atypical Conditions

Atypical conditions represent non-recurring congestion due to higher than usual demand and/or major capacity reduction events. Atypical conditions may include incidents, severe weather events, planned special events (e.g., major sporting events and concerts), holiday and seasonal congestion, and homeland security events; and such conditions may occur during weekdays, weekends, and peak and off-peak periods. A major challenge of analyzing atypical conditions is that it is necessary to identify similar, comparable events that occur during both pre- and post-deployment periods. In order to make meaningful comparisons, comparable events need to share similar characteristics in terms of nature of the events, location, time of day, weekday or weekend, duration, and impact to traffic operations (e.g., number of lanes blocked). For the purpose of this evaluation, the focus will be on events and scenarios that will likely occur more frequently during the course of the evaluation. As such, the atypical conditions to be analyzed will include major and minor incidents, severe weather events, and planned special events.

Because these events can have significant impact on corridor operations, mobility performance will be analyzed separately from daily operations when these conditions exist. Incident conditions will be analyzed separately from non-incident conditions. Similarly, days in which weather conditions are deemed to affect corridor operations will be analyzed separately from days when weather conditions are not severe. These analysis periods are referred to in the evaluation as “event case studies.” The national evaluation team expects to perform two or three case studies on major incidents, two or three on minor incidents, two on severe weather events, and one or two on planned special events. For the most part, these case studies will consider the same performance MOEs as considered during non-incident conditions. One additional measure—"incident recovery time" will be considered only for traffic incident conditions. The evaluation will use the definition of "recovery time" from the FHWA in the 2010 Traffic Incident Management Handbook: the time between awareness of an incident and restoration of impacted roadway/ roadways to "normal" conditions (conditions typical during non-incidents for the roadways in question for the day of week and time of day).

The following annual events are good candidates to consider for the "event case studies":

- Marine Corps Air Station (MCAS) Miramar Air Show. This event typically occurs in October of each year. MCAS Miramar is adjacent to I-15 ICM corridor between SR 52 and Miramar Road.
- San Diego Chargers Monday night and/or Thursday night football games. The Chargers play at Qualcomm Stadium, south of the ICM corridor near the intersection of I-15 and I-8.
- College Football games, including San Diego State University regular season games and/or annual Poinsettia and Holiday Bowl Games (both played in December) at Qualcomm Stadium.

The overall analytical design of this analysis is a before vs. after comparison. The most desirable comparison, for incidents, is to find an incident that takes place during the post-deployment period that shares matching characteristics with an incident that takes place during the pre-deployment period while both incidents take place at approximately the same location, time of the day and day of the week. Knowing that the "exact" matches will be very difficult to find, the evaluation will look for comparable incidents that share similar characteristics.

As described in Section 2.1.2, it will be important that the San Diego site team alerts the national evaluation within 72 hours of a candidate "event case study" occurrence so that special, ad hoc data collection associated with other evaluation analyses—e.g., the "pulse" traveler surveys included in the Traveler Response Analysis—can be initiated within a few days. The national evaluation team will provide the San Diego site team with a "watch list" of the types of events that are to be reported to the national evaluation team. Development of that watch list will entail a "cluster analysis" of historic incident data to identify frequency and patterns of incidents, if any, in the corridor and number of "hot spots" that are prone to incidents. This cluster analysis will help identify locations for the national evaluation team to focus on finding matching incidents. More importantly, the analysis will allow the national evaluation team to identify the types of incidents that have a higher possibility of reoccurring. Execution of this cluster analysis depends upon historic incident data to be provided by the San Diego site team.

The AMS model will be used to generate trip- and person-based throughput measures for the event case studies. That is consistent with the overall approach of using AMS as the source for those measures that cannot be effectively developed based on field data.

2.4.4 Evaluation of ICM Strategies

One of the goals of the ICM national evaluation is to determine, to the extent possible, the marginal contribution of individual ICM strategies to corridor performance. This will be very challenging given that ICM is inherently a synergistic endeavor in which ultimate success depends on a wide range of enabling actions and capabilities. The evaluation will employ the following techniques in an attempt to determine impacts of individual strategies or groups of strategies on corridor mobility performance.

- Utilization of Traveler Survey Data: The national evaluation team will draw upon the data collected through traveler surveys that will be conducted as part of the Traveler Response Analysis to better understand what aspects of an individual strategy or a group of individual ICM strategies led to what sorts of traveler responses. The national evaluation team will compare the field data with the survey responses to investigate the causal effect to determine the effectiveness of the strategy or strategies in changing travelers' behavior. For instance, during a major freeway incident that has been targeted for through the cluster analysis, information regarding the incident and potential delay due to the incident was disseminated to the public via 511 as well as roadside DMS's. In addition, messages to promote route- and mode-shifts were disseminated to both pre-trip and en-route traveler information devices. The pulse surveys will ask travelers if they received disseminated information and the effect of such information to their travel decisions. The survey results will provide an indication as to which strategies actually caused people to make a travel decision and change travel behavior. The national evaluation team will also analyze the traffic and transit data from the field to observe the mobility performance during the incident to understand the effect of changes in travelers' behavior on corridor operations. The combined results of the mobility analysis and traveler response analysis can provide useful information to understand the impacts and contributions of individual strategies or groups of strategies on corridor performance.
- Comparative Scenario Analysis: The second technique is to compare two situations with equivalent transportation conditions but in which different ICM strategies were utilized. For example, during the post-deployment period, two comparable traffic incidents occurred at approximately the same location at the same time of the day during the regular morning commute. Traffic data suggested the travel demand were nearly identical prior and during the incidents. However, the ICM strategies implemented for the two incidents were different. The national evaluation team will perform a case study on the two incident scenarios and compare the corridor mobility performance. The performance comparison can help explain the comparative impacts and differences on mobility between different sets of strategies.

2.4.5 Performance Measure Calculation Procedures

The input data and procedures for calculating the MOEs are described in this section. The mobility performance MOEs are grouped in the following four categories: travel time, delay, throughput and travel time reliability. All MOEs in the Mobility Analysis will be reported by mode to capture person and transit use. The following classification of travel modes will be included in the analysis:

- Auto-Non HOT Lanes: Traveling by private vehicle using arterial segments or a combination of arterial segments and I-15 general purpose lanes.
- Auto-HOT Lanes: Traveling by private vehicle on roadway network with a portion of the trip on I-15 HOT lane.
- Transit: This includes (1) exclusive transit trip, either taking BRT only or using a combination of BRT and local bus or feeder bus route(s); and (2) "kiss and ride" trips where travelers being dropped off at BRT stations and taking BRT to destination.
- Auto-Park & Ride-Transit: Driving and parking vehicle at a park & ride lot and taking BRT to destination.

In addition to evaluate the MOEs for the entire corridor by mode, MOEs for specific O-D pairs will be evaluated. For the analysis, trip origins and destinations will be major residential areas, major employment centers, park & ride locations, transit centers, and/or major interchanges and intersections along the corridor. The national evaluation team will examine traffic and transit data from the baseline period and work with the San Diego site team to determine origins, destinations, and specific O-D pairs that are most representative for the region's trip patterns and most suitable for the evaluation.

2.4.5.1 Travel Time

Travel time (TT) for I-15 general purpose and HOT lanes as well as strategic arterials will be computed using the roadway detector data. Link travel times will be computed by applying the average detector station speed over the zone of influence for each detector station. As discussed in Section 2.4.2, link-level data will be aggregated to the segment and corridor levels.

Transit Travel Time will be calculated using the AVL data from BRT and local bus and feeder routes to and from BRT stations. Travel time for a transit-exclusive trip (i.e., using a local bus or feeder bus from an origin and connecting to BRT to a destination), the total travel time will be calculated as:

$$TT_{Transit} = TT_{Bus} + Mean\ Waiting\ Time + TT_{BRT}$$

Travel time for an auto-park & ride-transit trip will be calculated as:

$$TT_{P\&RTransit} = TT_{PV} + Mean\ Waiting\ Time + TT_{BRT}$$

where TT_{PV} is the travel time in the private vehicle from the trip origin to the park & ride lot.

The average travel time for trips with a specified O-D pair by mode during a specified time period is calculated the sum of travel time of all individual trips (*tt*) divided by the total number of trips:

$$TT_{o-d} = \frac{\sum tt_{o-d}}{(Number\ of\ Trips)_{o-d}}$$

Trip-weighted average vehicle travel time (VTT) of the corridor across all modes is:

$$VTT = \frac{\sum[TT_{Mode} \times (Number\ of\ Vehicle\ Trips)_{Mode}]}{\sum(Number\ of\ Vehicle\ Trips)_{Mode}}$$

Trip-weighted average person travel time (PTT) of the corridor across all modes is:

$$PTT = \frac{\sum[TT_{Mode} \times (Number\ of\ Person\ Trips)_{Mode}]}{\sum(Number\ of\ Person\ Trips)_{Mode}}$$

2.4.5.2 Delay

Delay is calculated as the total observed travel time less the travel time under uncongested, light traffic conditions. Delay will be reported in terms of both vehicle-hours and person-hours of delay.

$$Vehicle\ Delay(VD) = [(Average\ TT) - (Free - Flow\ TT)] \times Number\ of\ Vehicles$$

$$Person\ Delay(PD) = [(Average\ TT) - (Free - Flow\ TT)] \times Number\ of\ Persons$$

Delay for a transit-exclusive trip will be calculated as:

$$Transit\ Vehicle\ Delay(TVD) = \{TT_{Transit} - Scheduled\ TT_{Transit}, or\ 0\ if\ (TT_{Transit} - Scheduled\ TT_{Transit}) < 0\}$$

$$Transit\ Passenger\ Delay(TPD) = TVD \times Number\ of\ Passengers$$

Delay for an auto-park & ride-transit trip will be calculated as:

$$Delay = VD + TVD$$

2.4.5.3 Throughput

Vehicle Throughput (VT) is a measure of the number of vehicles that are served in one direction of a facility during the analysis period. Vehicle throughput on each link of I-15 general purpose and HOT lanes will be measured using Caltrans's detectors, while vehicle throughput on arterials will be estimated using detectors on arterials. The number of existing and planned detectors on arterials, as illustrated in Figure 2-3, should provide the coverage sufficient for calculating vehicle throughput for arterial routes. The observed vehicle counts will be used to represent the vehicle volumes for the link where the detection is located. Links for arterial routes will be determined based on the locations of detection. Arterial vehicle throughput will be calculated using the link vehicle volumes.

Person Throughput (PT) is the total number of people serviced in the segment, O-D pair, or corridor during the analysis period. It is the product of the number of specific classes of vehicles (transit, SOV, HOV vehicles) traversing a length of roadway times the average number of occupants in each vehicle class.

$$PT = VT \times AVO$$

Person throughput will be computed for each travel mode and estimated using average vehicle occupancy rates (for freeway general purpose, HOT lanes and arterials) and transit passenger counts. The total corridor person throughput is computed using the following equation:

$$PT_{Total} = PT_{GP\ Lanes} + PT_{HOT\ Lanes} + PT_{Arterial} + PT_{Transit}$$

VMT is a common measure of throughput. It is the product of the number of vehicles traveling over a length of roadway times the length of the segment of roadway. It is computed using the following equations:

$$VMT_{Link} = Volume_{Link} \times Link\ Length$$

$$VMT_{Total} = \sum VMT_{Link}$$

VMT will be computed for I-15 general purpose lanes, HOT lanes and arterials using detector data.

Person-Miles Traveled (PMT), similar to VMT, is a measure of throughput and is the product of passenger throughput times the length of segment of roadway. PMT is computed using the following equations:

$$PMT_{Link} = PT_{Link} \times Link\ Length,$$

$$where\ \ PT_{Link} = PT_{Link,GP\ Lanes} + PT_{Link,HOT\ Lanes} + PT_{Link,Arterial} + PT_{Link,Transit}$$

$$PMT_{Total} = \sum PMT_{Link}$$

Segment- and corridor-level PMT is computed by summing all the link-level PMTs across all modes and all links defined in the segment or corridor.

Vehicle-Hours Traveled (VHT) is the total vehicle hours expended traveling on the roadway network in a specified area during a specified time period. It is the product of vehicle travel time times the length of roadway segment traveled.

$$VHT_{Link} = TT \times Volume_{Link} \times Link\ Length$$

$$VHT_{Total} = \sum VHT_{Link}$$

Person-Hours Traveled (PHT), similar to VHT, is the total person hours expended traveling on the roadway network in a specified area during a specified time period. PHT takes into account all occupants (drivers and passengers) in vehicles traversing on the network, including transit passengers. PHT is the product of person travel time times the length of the roadway segment traveled.

$$PHT_{Link} = TT \times (Number\ of\ Persons)_{Link} \times Link\ Length$$

$$PHT_{Total} = \sum PHT_{Link}$$

2.4.5.4 Travel Time Reliability

Travel Time Index (TTI) is a ratio of the travel time during the peak period to the time required to make the same trip at free-flow speeds. A value of 1.2, for example, indicates a 30-minute free-flow trip requires 36 minutes during the peak period. TTI is calculated in the following equation:

$$TTI = \frac{\left[\frac{Average\ TT}{Free - Flow\ TT} \times VMT\right]_{Freeway} + \left[\frac{Average\ TT}{Free - Flow\ TT} \times VMT\right]_{Arterial}}{VMT_{Freeway} + VMT_{Arterial}}$$

Freeway free-flow travel time will be computed from free-flow speed. Freeway free-flow speed will be computed using Caltrans's detector data as the 85th percentile speed during periods free of incidents, maintenance, and construction; when volumes are less than 1,000 vehicles per hour per lane (vphpl); during daylight hours only; and under dry pavement conditions. The 85th percentile speed is the speed at or below which 85 percent of a sample of free flowing vehicles is traveling.

Free-flow travel time for arterial routes will be derived using travel time data from detectors on arterials. Arterial free-flow travel time will be the average travel time during periods of low volume, free of incidents, maintenance, and construction; and under dry pavement conditions.

80th, 90th and 95th Percentile Travel Times describe how much delay will be on the heaviest travel days. The 80th percentile travel time is the travel time at or above which 80 percent of a sample of free flowing vehicles is traveling. The percentile travel times estimate how bad delay will be on specific routes during the heaviest traffic days. Percentiles are estimated from *N* measurements as follows:

$$n = \frac{p}{100} \times N + \frac{1}{2}$$

where, *p* is the *p*th percentile. Rounding the result *n* to the nearest integer, and then taking the value that corresponds to that rank to obtain the value of the *p*th percentile.

For example, given the numbers 20, 25, 28, 30, 30, 32, 36, 36, 40, 42, the rank of the 80th percentile would be

$$n = \frac{80}{100} \times 10 + \frac{1}{2} = 8.5$$

Thus the 80th percentile is the ninth number (rounding 8.5 up to 9) in the sorted list, 40.

Percentiles of travel time for freeway will be computed from the corresponding percentiles of speed from detectors, while percentiles of travel time for arterial routes will be calculated using the field travel time data directly.

Planning Time Index (PTI) represents the extra time cushion needed during peak traffic periods to prevent being late. It is the ratio of the total time needed to ensure 95 percent on-time arrival at a downstream destination compared to free-flow travel time.

$$PTI = \frac{\left[\frac{95th\ Percentile\ TT}{Free - Flow\ TT} \times VMT\right]_{Freeway} + \left[\frac{95th\ Percentile\ TT}{Free - Flow\ TT} \times VMT\right]_{Arterial}}{VMT_{Freeway} + VMT_{Arterial}}$$

Buffer Index (BI) represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival. While PTI shows the total travel time that is necessary, BI shows the additional travel time that is necessary. BI can be calculated for each freeway segment as:

$$BI(\%) = \frac{95th\ Percentile\ TT - Average\ TT}{Average\ TT}$$

A weighted average can be calculated using VMT or PMT as the weighting factor. A weighted average for more than one roadway segment could be computed as:

$$BI_{Corridor} = \frac{\sum(BI_{Link} \times VMT_{Link})}{\sum VMT_{Link}}$$

Variance in travel time is another indicator for travel time reliability. It describes how travel time varies over time and the impacts of this variance on corridor users. Variance in travel time is expressed in terms of standard deviation of measures travel time as shown in the following equation:

$$s^2 = \frac{\sum(Travel\ Time\ of\ ith\ Trip - Mean\ Travel\ Time)^2}{n - 1}$$

Where *s* is standard deviation of travel time and *n* is the number of sample trips.

2.4.6 Exogenous Factors

Exogenous factors that may influence evaluation of corridor mobility performance include significant changes in:

- Monthly unemployment rates for the region
- Average monthly gas prices for the corridor area
- Locations and timing of land-use development within and immediately outside of the corridor and economic and traffic impact studies and other relevant documents related to the development
- Changes in transportation policies and timing of policy implementations
- Timing and documentation on other non-ICM transportation system changes, such as changes in numbers of parking spaces at major employment centers and changes in numbers of employers participated in telecommuting.

The national evaluation team expects the San Diego site team to monitor the above exogenous factors and provide necessary information and data to the national evaluation team to investigate the impacts of those factors on overall corridor performance.

In addition, data from the I-15 detectors and BRT passenger counts within the corridor will be compared to data from I-5, I-805, I-8, and other transit routes outside the corridor as listed in Section 2.2.10 to determine if overall travel demand and patterns in the corridor have changed dramatically between evaluation periods. If traffic demand and patterns appear to have shifted radically, the national evaluation team will use a trend analysis to examine how factors such as changes in unemployment rates, gas prices, and land-use development have impacted travel conditions between the pre- and post-deployment periods.

To control for and attempt to understand the impact of exogenous factors, the national evaluation team will extract ICM-related impacts using one or a combination of the following methods:

- Utilizing AMS model to estimate the impact of ICM in absence of exogenous factors;
- Isolating and separately analyzing data associated with normal daily conditions vs. atypical conditions (incidents, constructions, and severe weather); and
- Utilizing traveler surveys to identify the ICM and non-ICM influences on travel decisions.

Table 2-4 summarizes the national evaluation team's approach to control and understand the impact of exogenous factors.

Table 2-4. Methods to Control Exogenous Factors

Exogenous Factor	Control Method
Unemployment	• Utilizing AMS model to estimate the impact of ICM in absence of changes in unemployment rates
Gas Prices	• Utilizing AMS model to estimate the impact of ICM in absence of changes in gas prices • Utilizing traveler surveys to identify the ICM and non-ICM influences on travel decisions
Land-Use Development	• Utilizing AMS model to estimate the impact of ICM in absence of land-use development • Isolating and separately analyzing data associated with land-use development
Major Roadway Constructions Outside of the Corridor	• Utilizing AMS model to estimate the impact of ICM in absence of constructions • Isolating and separately analyzing data associated with major constructions • Utilizing traveler surveys to identify the ICM and non-ICM influences on travel decisions
Changes in Transportation Policies	• Utilizing AMS model to estimate the impact of ICM in the absence of policy changes • Utilizing traveler surveys to identify the ICM and non-ICM influences on travel decisions

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2.5 Risks and Mitigations

Successful evaluation of the mobility performance is dependent on the completeness and comprehensiveness of data from the site. While it appears that most of the data required to do the analysis will be available, there are some areas of gaps and uncertainty which in turn pose challenges and risks to the analysis. Table 2-5 identifies the areas of data uncertainty and the risks associated with this analysis and the national evaluation team's response plan for each risk.

Table 2-5. Risks and Mitigations

Risk	Mitigation Strategy
1. Matching of comparable incidents or events occurring at the same location during the same period of the time.	If no comparable incidents can be found and matched during pre- and post-deployment periods, the national evaluation team will look for incidents that may closely resemble the targeted incident and document the differences between the incidents and key assumptions used, and explain how various factors (such as differences in operating conditions, ICM strategies used, etc.) may be attributable to the results.
2. Faulty or failing data collection technology during evaluation period. A possibility exists that some data collection devices (such as roadway detectors, AVL, automatic passenger counters, etc.) will become inoperable during the evaluation period.	If and when data collection devices fail, the national evaluation team will perform internal range checks and observe time series patterns to detect faulty data. Faulty data will be excluded from the analysis.
3. Lack of sufficient detection density on non-parallel arterials or secondary arterials. Detectors may not be instrumented on all possible diversion routes.	The national evaluation team will use the counts from nearby detectors (including those on nearby arterials and ramps) to interpolate data and balance the network. AMS results can also be used to support analyzing volume-related MOEs (such as throughput and other vehicle- and person-weighted measures). In addition, traveler survey will be used to supplement and validate data interpolation as well as AMS results.
4. Availability of arterial maintenance, construction, and incident data during baseline period and the uncertain state of data systems for such data in the post-deployment period.	The national evaluation team will observe arterial volume and travel time data to identify abnormal traffic conditions and contact local agencies within 72 hours to verify if such abnormalities are caused by maintenance, construction activities, or incidents on arterials.

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3.0 SAFETY ANALYSIS

This chapter provides an overview of the approach to the safety portion of the Corridor Performance Analysis, including a discussion of the evaluation hypothesis to be tested and the associated MOE.

3.1 Analysis Overview

Figure 3-1 graphically summarizes the approach to this analysis. The safety analysis focuses on the U.S. DOT ICM evaluation hypothesis pertaining to how ICM-related enhancements impact corridor performance in terms of safety. Quantitative analysis of corridor safety performance is a core component of the evaluation in that it provides assurance that the increased operational performance for ICM does not come at the cost of increased risk to the traveling public. This analysis includes a before-after comparison of the impact of ICM strategies on corridor safety performance. The MOE for this analysis is the accident rate per vehicle mile traveled. Corridor safety performance will be evaluated for corridor segments and overall for the entire corridor.

There are important limitations to this analysis. It is not feasible to evaluate safety for individual ICM components due to the interrelated way in which these operate to impact overall safety as well as insufficient sample sizes of accidents at this most granular level of evaluation. Additionally, safety evaluation will be restricted by time and conditions to maximize the degree to which the underlying transportation environment is similar before and after ICM deployment. Finally, only the road transportation mode as measured by numbers of vehicles can reasonably be evaluated. BRT and bus transit safety analysis are not included.

As indicated in Figure 3-1, U.S. DOT has identified a single, broad hypothesis related to ICM safety impacts:

> *Safety: ICM implementation will not adversely affect overall safety outcomes, and better incident management may reduce the occurrence of secondary crashes.*

The broad hypothesis suggests two overall assessments that might reasonably be made: 1) assessing an overall lack of harm for the ICM implementation, and 2) demonstrating one potential mechanism (i.e., reduction of secondary crashes) by which the ICM implementation may improve safety. The national evaluation team has judged that there are not appropriate data available to complete the second evaluation. Instead, only the first aspect of the hypothesis will be examined in this test plan.

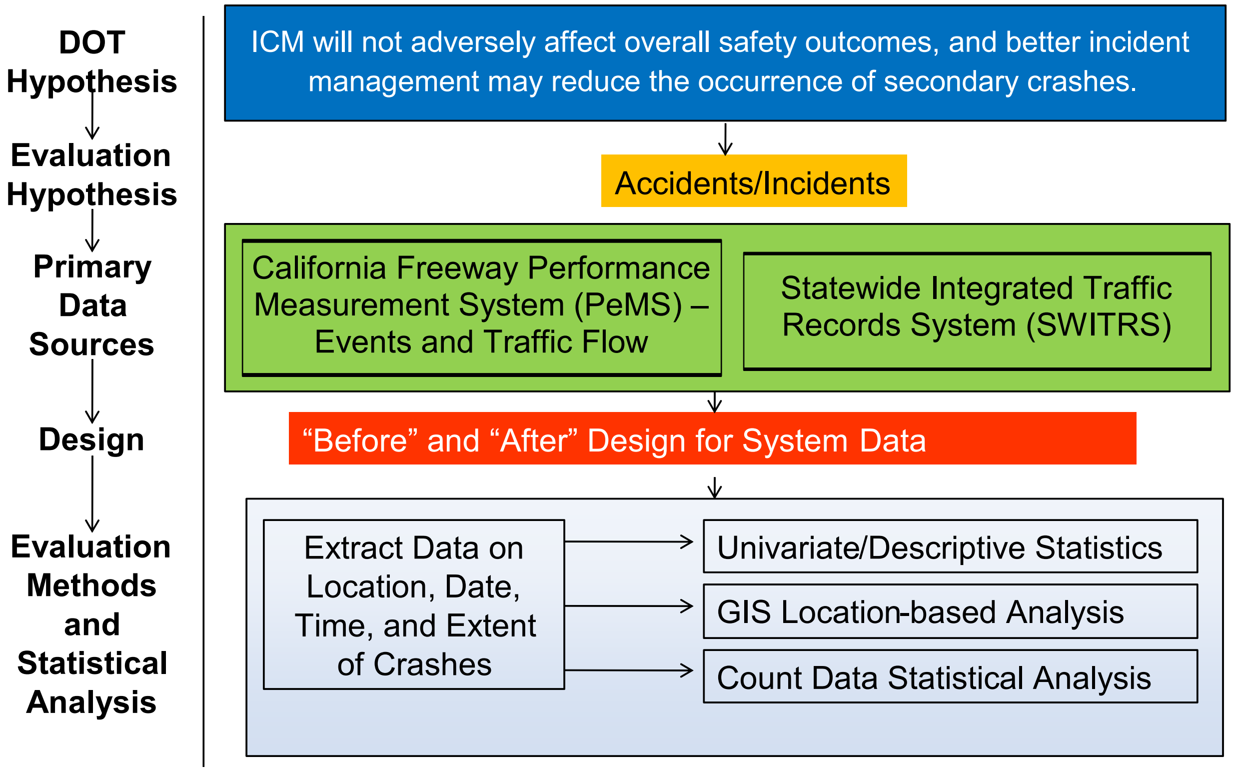

Figure 3-1. Overview of Safety Analysis

Overall ICM Safety Hypotheses:

- Safety as measured by vehicle crash rates per vehicle mile driven will not be significantly higher under ICM deployment than before deployment.

This evaluation hypothesis references the overall, synergistic impacts of the entire ICM deployment. The safety impacts of specific ICM strategies or groups of strategies cannot rigorously be identified with the data anticipated to be available. Additionally, the hypothesis has been limited to typical high traffic-volume conditions (e.g., rush hour) to enhance the model sensitivity and to avoid the effects of exogenous factors that cannot easily be controlled.

Table 3-1 identifies the specific data and MOE that will be used to test the evaluation hypothesis. The particulars of each data type are elaborated in Section 3.2. The overall design of this analysis includes simple data summaries by geographic location of accidents before and after the ICM deployment, and a corresponding general log-linear model of crash count data with corresponding estimation of the rate of accidents after ICM deployment compared to before.

Table 3-1. Safety Analysis Data Elements, MOE, and Hypothesis

Data Element	MOE	Hypothesis
Quantitative Data		
1. Vehicle Miles Traveled*	• Accident rate per vehicle mile traveled	• After normalizing for corridor locations and conditions, and restricting the analysis to typical high traffic-volume conditions, safety as measured by vehicle crash rates per vehicle mile driven will not be significantly higher under ICM deployment than before deployment.
2. Events – Incidents, Weather Events, and Special Events*		
3. Crash Data Records		
Qualitative Data		
This test plan utilizes no qualitative data		

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* These data elements (or, in the case of Vehicle Miles Traveled, MOE) will be available from the mobility portion of the Corridor Performance Analysis.

3.2 Quantitative Data

This chapter identifies the quantitative data elements to be used in the safety portion of the Corridor Performance Analysis. Table 3-2 summarizes the data requirements for the safety portion of the Corridor Performance Analysis. The details associated with the source, timing, and other aspect of each data element are discussed in the sections that follow.

Table 3-2. Quantitative Data Summary

Data Element	Location		Data Collection Frequency	Data Collection Period		Data Collection Responsible Party	Data Transmittal
	Start	End		Start	End		
1.1 VMT	Northern boundary of corridor	Southern boundary of corridor	Daily (for peak traffic periods)	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
2.1 Log of Maintenance Activities	Northern boundary of corridor	Southern boundary of corridor	Daily	Feb 2012	July 2014	ICMS Data Hub	Daily (UMD Data Feed)
2.2 Log of Construction Activities	Northern boundary of corridor	Southern boundary of corridor	Daily	Feb 2012	July 2014	ICMS Data Hub	Daily (UMD Data Feed)
2.3 Incident/ Collision Records	Northern boundary of corridor	Southern boundary of corridor	By incident	Feb 2012	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
2.4 Weather Information Records	Northern boundary of corridor	Southern boundary of corridor	Daily, and hourly during severe weather events	Feb 2012	July 2014	San Diego Site Team and National Evaluation Team	Monthly (Email to National Evaluation Team; National Evaluation Team from National Weather Service Reports)
2.5 Special Events	Within the region	Within the region	By event	Feb 2012	July 2014	San Diego Site Team	Monthly (Email to National Evaluation Team)

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3.2.1 Vehicle Miles Traveled (VMT)

VMT is an important MOE for the mobility analysis. It is calculated using vehicle count data and roadway geometry using data identified in Section 2 of this plan. For the safety analysis, total vehicle miles traveled by I-15 general purpose and HOV lanes, and arterials will be provided by the national evaluation team for the mobility analysis. The VMT data will cover the baseline time period (pre-deployment) of February 2012 to February 2013, and also the post-deployment period of approximately July 2013 to July 2014. The VMT will be reported down to a corridor segment level and will represent peak traffic volume periods under typical conditions. The safety modeling could incorporate VMT to as low as the daily level, but whatever lowest level of temporal aggregation available will be used.

3.2.2 Maintenance and Construction Activities, Incidents, Severe Weather Events and Special Events

To establish that crash data in the pre-deployment and post-deployment periods represent comparable operating conditions, several sources of data need to be reviewed. The details of the maintenance and construction activity data are provided in Section 2.2.6 and the Incident, Severe Weather Events, and Special Events data are provided in Section 2.2.7. The tabulations of these events will be a data element in the safety analysis, used to identify a subset the safety records that may reasonably be attributed to typical traffic operations.

3.2.3 Incident/Collision Data

To facilitate the calculation of the safety MOE, the following data is needed:

- Geocoded location of the incident
- Date and time of incident
- Number of vehicles impacted

Traffic accident data for the I-15 corridor are expected to be directly available through the Freeway PeMS via the real-time CHP's Media feed which provides information on incidents on the freeway system. The event data include the location of the event as described by the freeway, direction and milepost, as well as the start time and duration of the event. While this data set is available, it does have some shortcomings. Accidents on arterial roads are not included in this database and the number of vehicles impacted is not reported. Since this is a real-time data feed, this data source is also the "noisiest" in terms of data quality and consistency.

The CHP's media feed also serves as an input to the CHP's Statewide Integrated Traffic Records System (SWITRS). SWITRS then is shared in batch-mode to Caltrans, where the accident records are manually scrubbed and geo-coded into the Traffic Accident Surveillance and Analysis System (TASAS). The TASAS data is then included back in PeMS; However, access to this data is limited to Caltrans personnel. Since the data from CHP needs to be manually processed, TASAS data lags by typically 18-24 months. As such, the use of TASAS data might be restricted to historical and trend comparisons.

In regard to arterial data, the San Diego site team is working with partner agencies to establish and implement a formal process to collect arterial incident data. If these data become available during the evaluation period, they will be utilized to generate safety MOEs. Otherwise, the MOE will necessarily include only freeway data.

3.3 Qualitative Data

No qualitative data elements are currently required for use in safety portion of the corridor performance analysis.

3.4 Data Analysis

This section describes how the gathered data will be analyzed to assess safety impact. Specifically, the approach to testing the hypotheses and/or drawing conclusions will be discussed, including statistical and analytical processes and tools.

3.4.1 Hypothesis Testing

As discussed in Section 2, the safety related ICM evaluation hypothesis tests whether the rate of crashes after ICM deployment is definitively higher than prior to ICM deployment.

3.4.2 Data Aggregation

To compute the safety performance measures, crash data records will need to be geocoded to a location and include date and time information. The geocoded data can then be attributed to a corridor segment and to one of three types of roadways in the corridor; I-15 general purpose lanes, I-15 HOV/HOT lanes (if possible), and arterial roads (if possible). Crash data records in the form of counts of vehicles will be associated with a corresponding number of vehicle miles traveled for a particular time period and segment. The definition of segments and of VMT are provided in the Section 2.

The time period for the evaluation will be the pre-deployment baseline period of February 2012 to February 2013, and the post-deployment period of approximately July 2013 to July 2014. Each period represents one calendar year, so it is assumed that the two time periods are adequately representative of seasonal variability that might occur in crash data.

3.4.3 Typical and Atypical Conditions

The mobility analysis identifies the primary benefits of ICM expected to occur during high-demand conditions and major capacity reduction events such as major incidents. Daily recurring congestion conditions are those that offer the best opportunity to fairly evaluate safety differences before and after ICM deployment. Therefore, the safety analysis will be conducted only for crashes occurring on non-holiday weekdays during the morning and evening commute, as defined in the mobility analysis. Furthermore, periods of time with exceptional events, to the extent that such can be identified, will also be removed from the analysis. Exceptional events are limited to conditions that cannot be considered to reasonably occur in both the pre- and post-deployment periods. This might include a significant weather event such as a hurricane, or a hazmat spill that completely shuts down a segment for an extended period. It does not include incidents that might occur infrequently, but still not unusually, during the high volume time periods, such as a serious accident. Crash data removed from the analysis over a particular calendar period in either the pre-deployment or post-deployment period will also be removed for the same calendar period in the other deployment period to maintain temporal equality between the sets of data.

Note that there is a legitimate hypothesis that safety could be impacted by ICM deployment during atypical conditions. However, the only way that this could fairly be evaluated in a pre- and post-deployment scenario would be to identify a set of atypical conditions occurring in both time periods that were sufficiently similar so as to provide a strong probability that the observed safety differences in the two periods might be attributed to the ICM deployment condition and not be confounded with the safety characteristics of the events themselves. It is judged that this assumption is too onerous to expect to actually occur.

3.4.4 Statistical Modeling

A subset of the crash data will be generated to include only those crashes within the evaluation corridor and within the daily time periods of interest. Data will be separated into a pre-deployment and a post-deployment period. To the extent possible, each time period will be of equivalent calendar length, one full calendar year. Data analysis and presentation will be provided in two different manners:

1) Descriptive statistics and data summaries
2) Statistical modeling and testing of hypotheses

3.4.5 Descriptive Statistics and Data Summaries

An important understanding of crash statistics will come from simple summaries of the rate of crashes per vehicle mile traveled in both the pre-deployment and post-deployment periods during typical peak traffic volume periods (morning and evening rush). Such summary statistics will be calculated by dividing the total vehicles in the crash database records by the corresponding estimation of VMT from the mobility analysis. Estimates will be provided at the corridor level for the full evaluation period as well as separately being calculated for segments of the corridor. Corridor segments will correspond to those identified in the mobility analysis.

These data summaries will be provided in tabular form and will also be shown superimposed on a GIS map to provide a visual reference for prevalence of crashes and a comparative difference before and after ICM deployment.

3.4.6 Statistical Modeling and Testing of Hypotheses

The crash data will be in the form of a count of vehicles (Vi) involved in a crash in one corridor segment of a particular roadway type over a particular time period (morning or evening rush) on one day. If crash counts are too low to fit a model by day, counts may be aggregated to a week. At its most general level, the Vi may be sums of vehicles from multiple crash records. These counts may be zero if no crash record is present. Associated with each vehicle count data record will be the estimated total VMT for the conditions of that record as well as separate potential predictors for the count to include:

- ICM deployment (pre or post-deployment)
- Time of Day (morning or evening commute)
- Corridor segment
- Roadway Type (including roadway geometry)

The vehicle data will be evaluated using count models. A standard statistical model for count data posits that under certain conditions, counts (for instance the number of crashes on a particular road segment over a period of time) may follow a Poisson distribution. A Poisson distribution has the form:

$$P(X = c) = \frac{\lambda^c e^{-\lambda}}{c!}$$

Where

X is a random variable that can take any non-negative integer value, c

λ is the parameter of distribution (and also its mean and variance)

Consequently, the crash data will first be fit to such a model. The model will include the predictor variables as well as an offset for the VMT (log transformed). Model diagnostics will be examined to determine the goodness of fit for this model. Models of this type of data frequently must be adjusted at the least to account for overdispersion. This means that the data show variability, likely due to additional unmeasured factors not accounted for by the subset of factors evaluated in the model. In this case, if the Poisson model is not entirely reasonable, a separate negative binomial model will also be assessed. The negative binomial model naturally accounts for overdispersion relative to the Poisson model. If each observed data element is consistent with an observation from an underlying Poisson distribution, but the underlying Poisson distributions vary from data point to data point as a Gamma distribution, the entire process may be modeled as a negative binomial distribution. A Gamma distribution is a non-negative valued distribution which is not symmetric and usually has a large upper tail. The negative binomial model is reflected by the distribution function

$$P(X = c) = \frac{\Gamma\left(\frac{1}{\sigma^2} + c\right)\left(\frac{1}{\sigma^2}\right)^{\frac{1}{\sigma^2}} \lambda^c}{c!\,\Gamma\left(\frac{1}{\sigma^2}\right)\left(\lambda + \frac{1}{\sigma^2}\right)^{\left(\frac{1}{\sigma^2}+c\right)}}$$

Where

X is a random variable that can take any non-negative integer value, c

λ is the overall Poisson parameter

σ^2 is the variance of the Poisson parameters

This may be reasonable in the case of the crash data if the Poisson distribution of counts of accidents varies from day to day, perhaps based on a large number of unmeasured factors relating to the behaviors and dispositions of the drivers on the roads.

The Poisson and negative binomial models will each generate cumulative probabilities of counts that can be compared to the actual count distributions observed in the data to determine which model best fits the data.

Following fitting of a best model, the statistical hypothesis test for the ICM impact on number of crashes will be examined. The model will provide an estimate for the change in odds of a crash at the same conditions after ICM deployment as compared to before. A p-value will be produced for the test of a null hypothesis that crash odds following ICM deployment are less than or the same as before deployment. If the p-value is less than 0.05, it will provide evidence that the rate of crashes in the post-deployment period is greater than that in the pre-deployment period. Otherwise, there will not be adequate evidence of a higher crash rate.

Note that under the outcome of a significant effect, ICM deployment is not proven to be the cause of the safety change, only to be correlated with it. Further controlled evaluation tests would be called for to assess the degree to which causation might be considered a possibility. Conversely, failure to reject the hypothesis does not prove that safety was not degraded, only that data do not provide strong evidence of it. For the latter issue, the crash data in the baseline period will be used to determine an approximate effect size that might be identified with high probability (95 percent or more) in the post-deployment data. This will allow a statement of the true magnitude of safety difference after deployment compared to before deployment that would have been expected to be highly likely to have resulted in a statistically significant outcome of reduced safety.

Statistical summaries and modeling will be conducted in SAS® v 9.2. The primary models will be fit using the PROC GENMOD procedure. GENMOD is the general linear models procedure in SAS.

3.5 Risks and Mitigations

Successful evaluation of the safety performance is dependent on the completeness and quality of the evaluation site data as well as the crash records. While it appears that most of the data required for the analysis will be available, there are some areas of gaps and uncertainty which could pose challenges and risks to the analysis. Table 3-3 identifies the risks associated with this analysis and the national evaluation team’s response plan for each risk.

Table 3-3. Risks and Mitigations

Risk	Mitigation Strategy
1. Lack of automated traffic volume counts on arterials.	The national evaluation team is working with the site to ensure adequate arterial detection (which is needed for the site's operations as well)
2. Crash data reporting will lag real time so that the post-deployment year's data will not be available in time to complete the evaluation.	The calendar months of crash data that are available in the post-deployment period will be compared only to the same calendar months in the pre-deployment baseline period. Alternatively, if ICMS feed logs can provide more timely crash data with equal quality and level of detail, these data may supplement that of the crash data reporting system.
3. Crash data will not be available with geocoding.	If the number of records is not too large, a manual coding effort could be undertaken, but this would require additional resources beyond those planned. Alternatively, data could be subset only at the grossest geographic level (e.g., county) with corresponding loss of specificity in modeling parameters. Some level of geo-coding is already included in the CHP Media feed but it is not consistent.

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U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

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