Integrated Corridor Management

Analysis, Modeling, and Simulation for the Interstate 15 Corridor in San Diego, California

Post-Deployment Analysis Plan

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Final Report—October 2016
FHWA-JPO-16-393

U.S. Department of Transportation

Produced by Cambridge Systematics, Inc.
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

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Technical Report Documentation Page

1. Report No. FHWA-JPO-16-393	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Integrated Corridor Management Analysis, Modeling, and Simulation for the I–15 Corridor in San Diego, California—Post-Deployment Analysis Plan		5. Report Date October 2016
		6. Performing Organization Code
7. Author(s) Vassili Alexiadis		8. Performing Organization Report No.
9. Performing Organization Name and Address Cambridge Systematics, Inc. 555 12th Street, Suite 1600 Oakland, CA 94607		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTFH61-12-D-00042
12. Sponsoring Agency Name and Address U.S. Department of Transportation Research and Innovative Technology Administration (RITA) 1200 New Jersey Avenue, SE Washington, D.C. 20590		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code HOP
15. Supplementary Notes The Government Task Manager for this task is James Colyar.		

16. Abstract

Post-Deployment Analysis, Modeling, and Simulation (AMS) activities focus on identifying impacts and benefits of the "as-deployed" Integrated Corridor Management (ICM) system. The "as-deployed" ICM strategies may differ from "as-planned" ICM strategies. The differences could include ICM strategies that are not successfully deployed, ICM strategies that are deployed differently from planned because of technical issues, and ICM strategies that are deployed differently to take advantage of enhancements or impacts not anticipated before deployment. Further, Post-Deployment AMS activities take full advantage of site-specific traveler behavior and response characterization efforts conducted by the Volpe Center and the ICM Evaluation contractor activities included in the post-deployment efforts. The objective of the Post-Deployment AMS efforts is to ensure that the models and methodologies can sufficiently replicate and evaluate corridor conditions and the proposed ICM strategies after ICM deployment. In this stage, the AMS contractor and the Demonstration site staff will confirm, refine, and validate the parameters/assumptions that serve as the basis for the ICM strategies in these models. These updated and enhanced models and methodologies can provide further insight on ICM implementation and other operational benefits that will help guide the demonstration projects, future ICM deployments, as well as assist in the evaluation activities.

This Post-Deployment Analysis Plan for the I–15 Corridor outlines the various tasks associated with the application of the ICM AMS tools and strategies to this corridor in order to support the post-deployment analysis and demonstration of the proposed ICM system, and assist in the evaluation effort.

17. Key Word Integrated Corridor Management, ICM, post-deployment analysis, incident, strategies, traveler information, pioneer corridor, analysis plan, Analysis Modeling Simulation (AMS), performance measures, San Diego, California, CA, I–15	18. Distribution Statement No restrictions.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 47	22. Price N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgments

The following individuals provided significant support in the development of this document:

- San Diego Site Team Alex Estrella, Peter Thompson, Mike Calandra, and Matthew Juckes—(contractor to San Diego Association of Governments).
- U.S. DOT Integrated Corridor Management (ICM) Team—Robert Sheehan, James Colyar, Steve Mortensen, Brian Cronin and Karl Wunderlich (contractor to the U.S. Department of Transportation).
- Volpe Center Evaluation Team—Lee Biernbaum and Margaret Petrella.
- ICM Evaluation Contractor Team—Michael Waisley and Murat Omay (contractors to U.S. Department of Transportation).

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Chapter 1. Introduction and Project Scope

The objective of the ***Integrated Corridor Management (ICM)*** initiative is to demonstrate how intelligent transportation systems (ITS) technologies can efficiently and proactively manage the movement of people and goods in major transportation corridors. The ICM initiative aims to pioneer innovative multimodal and multijurisdictional strategies and combinations of strategies that optimize existing infrastructure to help manage congestion in our nation’s corridors. There are many corridors in the country with underutilized capacity in the form of additional transit capacity—bus, rail, bus rapid transit (BRT), etc.—undersaturated parallel arterials, and inefficient utilization of principal facility resources. Each of these corridors could benefit from the application of ICM technologies and strategies.

The maturation of ITS technologies, growing availability of supporting data, and emerging multiagency institutional frameworks make ICM both practical and feasible. Several freeway, arterial, and transit optimization strategies are in widespread use across the United States, with most currently managed by individual local agencies on an asset-by-asset basis. For those that are managed by a larger regional agency, the approach is still generally uncoordinated and involves little or no integration among the different resources available on the corridor. By appropriately applying ICM strategies, the agencies responsible for managing these corridors can reduce congestion and improve overall productivity. Furthermore, providing travelers with relevant information on transportation alternatives can encourage a redistribution of trips to less congested routes, modes, or times of day, which further reduces congestion and affords travelers a greater mobility and increased safety.

The focus of this ICM Post-Deployment assessment is to evaluate to what extent ICM technologies can efficiently and proactively manage the movement of goods and people in a major transportation corridor. Specifically, this project will investigate the impacts of the ICM system in its “as deployed” state on Interstate 15 (I–15) in San Diego, using analysis, modeling, and simulation (AMS) tools and techniques developed and refined under both the current and previous phases of the program. Results from traveler behavior surveys conducted in the vicinity of the I–15 corridor by the Volpe Center will be used to inform model assumptions and to enable more accurate representation of true driver behaviors on I–15. The results of the post-deployment AMS will then be used to assess and validate the estimated impacts from the pre-deployment analysis.

The following is a summary of additional project objectives that will support these overall goals:

- Develop a post-deployment AMS Plan in collaboration with the ICM Demonstration Site staff to promote coordination of analysis efforts and coherent alignment of goals among this effort, the ICM Demonstration Site staff, and the ICM Evaluation team.

- Support the objective evaluation efforts of the Demonstration Site staff and enhance the ability of the modeling tools to accurately represent the deployed ICM strategies by identifying and facilitating improvements to AMS tools, techniques, and inputs.
- Manage the successful transition of modeling responsibilities from AMS Contractor to the ICM Demonstration Site staff and organizations, with workshops to promote the transfer of knowledge and technology.
- Support the integration of AMS tools and techniques into ongoing corridor management practices by the Demonstration Site staff.
- Provide technical documentation of AMS tool development, data sources, data processing methods, model calibration and validation procedures, and analysis techniques used to represent and evaluate ICM impacts.

This post-deployment analysis builds upon previous work that was completed under the pre-deployment AMS project (U.S. Department of Transportation (DOT) Contract DTFH61-06-D-00004), which examined the potential benefits of ICM on I–15 in San Diego prior to its realization in 2013. The pre-deployment analysis provided a detailed measure of expected impacts according to the planned design of the ICM project on I–15 prior to its deployment. Among the products from that pre-deployment analysis relevant to this current project are:

- An AMS Plan specifically tailored to the unique characteristics and conditions of the I–15 corridor.
- A baseline simulation model of the ICM corridor capturing all major roadways and transit facilities within the study area, calibrated and validated to state-of-the-art standards.
- An alternatives analysis methodology and application that enabled the comparison of several performance metrics of the I–15 corridor under various scenarios with and without ICM.

Work products associated with the pre-deployment analysis will be essential to the timely preparation of the tools and data needed for the current post-deployment analysis given the schedule constraints of the current contract. Consequently, the products from the pre-deployment analysis of I–15 in San Diego remain relevant to this current post-deployment analysis, and several references will be made throughout this document to the pre-deployment analysis. These references will be accompanied by summaries of procedures, models, methodologies, and outcomes, as appropriate, with the finer points available in the source document if more detail is desired. (Source: *Final Pre-Deployment Analysis Plan: Stage 3A Analysis, Modeling, and Simulation for the I–15 Corridor in San Diego, California.* Cambridge Systematics, Inc., for U.S. DOT. December 2011.)

This ***Post-Deployment Analysis Plan for the I–15 Corridor*** outlines the core tasks associated with the realization of the project goals and objectives described earlier. The organization of this analysis plan is as follows:

- **Chapter 2** provides a brief description of the I–15 Corridor in San Diego, California.
- **Chapter 3** describes the ICM strategies comprising the ICM deployment on the corridor.
- **Chapter 4** describes the AMS methodology.
- **Chapter 5** describes the performance measures use in the AMS.

- **Chapter 6** provides guidance for model calibration.
- **Chapter 7** describes the AMS approach and related tasks.
- **Chapter 8** provides the schedule and resource guide for the post-deployment AMS tasks.

Chapter 2. Interstate 15 Corridor Description

The Interstate 15 (I–15) study corridor in San Diego, California, extends from State Route (SR) 163 at its southern end to SR 78 at its northern end, for an overall length of approximately 20 miles. The study area is shown in figure 1, including freeway and arterials. Along this freeway corridor are arterials with the following interchanges with the freeway:

- Centre City Parkway.
- Pomerado Road.
- Rancho Bernardo Road.
- Camino Del Norte Road.
- Ted Williams Parkway (SR 56).
- Black Mountain Road.
- Scripps Parkway.

The I–15 corridor in San Diego has been utilized as a test bed for various intelligent transportation system (ITS) strategies identified in consultation with the San Diego Association of Governments (SANDAG) and other local stakeholders. The strategies incorporated into the deployed integrated corridor management (ICM) system are described in greater detail in chapter 3. The following sections provide an overview of the study corridor and describe the general analysis, modeling, and simulation (AMS) process.

In San Diego, the I–15 freeway carries eight to 10 lanes of traffic and functions as an important link between the urban core of San Diego and suburban cities to the northeast, including Poway, Mira Mesa, and Escondido, making it a heavily used commuter link between northern San Diego County and major employment centers to the south. It is one of three major north-south transportation corridors in San Diego County and is the principal inland route, serving local, regional, and interregional trips. The route is part of a major interregional goods movement corridor, as it connects Mexico to the south with Riverside County, San Bernardino County, and Las Vegas, Nevada, to the north. As of December 2011, average weekday traffic volumes ranged from 170,000 to 290,000 vehicles on the general purpose lanes of I–15, with approximately 20,000 additional vehicles using high-occupancy toll (HOT) lanes (or “Express Lanes”). Public transportation along the corridor includes bus rapid transit that runs on the I–15 managed lanes, and local bus transit lines that run on the neighboring arterials.

Figures 1 and 2 provide geographic context for the corridor and indicate the extent of the study area.

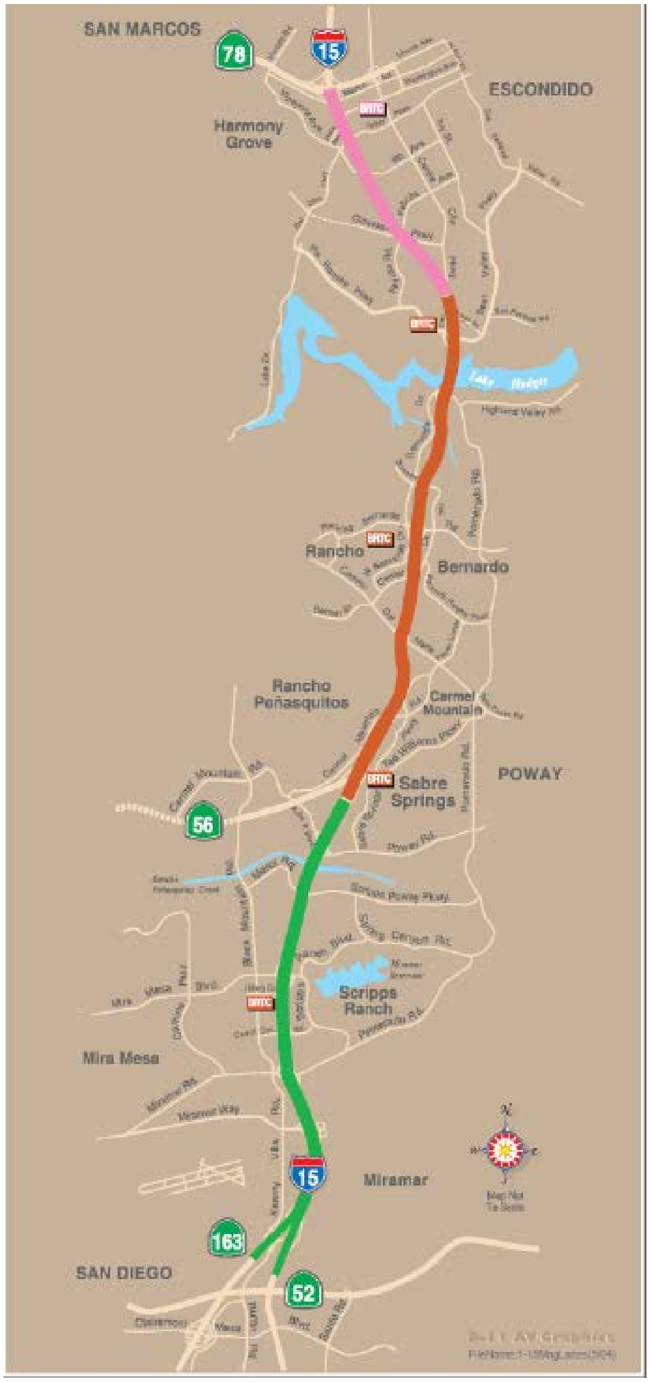

Figure 1. Map. Study area Interstate 15 corridor in San Diego, California.

(Source: Scope and Summary: I–15 ICMS Corridor in San Diego, U.S. Department of Transportation.)

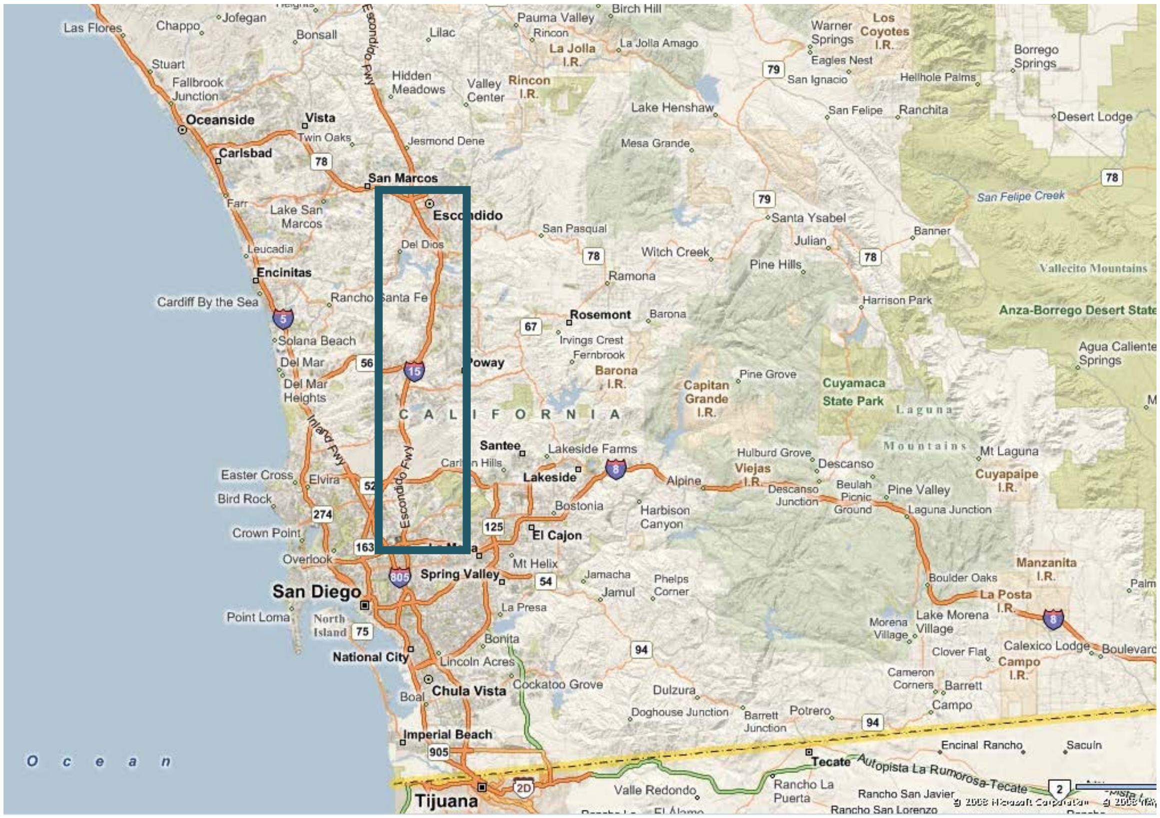

Figure 2. Map. Location and geographic boundaries of corridor.

(Source: San Diego Association of Governments.)

Chapter 3. Integrated Corridor Management Strategies

The San Diego Integrated Corridor Management (ICM) project focuses on five primary ICM goals:

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, San Diego Association of Governments (SANDAG) and its partnering agencies used investments in intelligent transportation systems (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 is expected to deliver information to commuters via the Internet and message signs, and 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:

- Provide corridor users with the operational condition of all corridor networks and components, such as travel times, incident information, and expected delays using changeable message signs, a new 511 app, and other commercial travel-time information sources.
- Use a decision support system with real-time simulation, predictive algorithms, and analysis to evaluate potential congestion mitigation and select/implement the optimal combination of mitigation strategies for the corridor.
- 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 multijurisdictional coordination of field devices such as lane controls, traveler information messages, traffic signal timing plans, and transit priority.

Components of the ICM deployment in San Diego include:

- A Decision Support System (DSS) that utilizes incoming monitoring data to assess conditions, forecast conditions up to 30 minutes in the future, and then formulate proactive recommended response plans (including selecting from preapproved plans) for consideration by operations personnel.

- En-route and pretrip traveler information using changeable message signs, a new 511 app, and other commercial travel-time information sources.
- Enhanced transit network information.
- Enhancement of the Integrated Transportation (Corridor) Management System (ICMS) regional information exchange network, a system which was enhanced using ICM funding.
- Adjustments to ramp meter timing to support diversion to or from the freeway.
- Upgrades to selected traffic signal systems, including new traffic signal coordination timings and responsive traffic signal control on two arterial streets paralleling Interstate (I–15), as well as on arterials connecting the freeway to parallel arterials.
- Active routing changeable message signs helping diverted drivers return to the freeway downstream of the incident (planned).
- Arterial street monitoring system, including additional traffic detectors.

Chapter 4. Analysis, Modeling, and Simulation Methodology

The approach used to model the Interstate 15 (I–15) Integrated Corridor Management (ICM) corridor integrates a range of proven analysis, modeling, and simulation (AMS) tools and ICM analysis resources to form a single coherent system that can be used for corridor planning, design, and operations. This involves combining tools with inherently different analysis resolutions—macroscopic-level simulations for modeling travel demand and microscopic-level simulations for modeling detailed driver behavior—to evaluate a variety of ICM strategies and scenarios.

For AMS of the I–15 corridor, macroscopic models are used to produce Origin-Destination trip tables that are supplied as inputs to the microscopic simulation models. The microscopic models are then used to simulate the behavior of individual drivers in response to various control strategies on the corridor and at junctions (e.g., freeway interchanges or arterial intersections), including shifts within and between travel modes. The methodology also provides methods for connecting the different analysis tools, including postprocessing modules that enable analysis of benefits and costs and the measurement of performance metrics.

Modeling Components

An overview of the various components used in the AMS framework is provided in the following sections.

Travel Demand Forecasting Model

Predicting travel demand requires analysis tools that appropriately consider destination choice, mode choice, time-of-day travel choice, and route choice, given a traffic state for each link in the network. When combined into a coherent demand modeling framework, the result can be used to predict future travel patterns from current traffic levels, forecasted household characteristics, and predicted employment characteristics.

The San Diego Association of Governments (SANDAG) regional Travel Demand Model (TDM) is used to develop the broader origin/destination matrices for the I–15 Corridor, which then are disaggregated by travel analysis zones to provide finer trip modeling resolution for simulation. Parameters from the TDM are used to model mode shifts in response to congestion and to ICM strategies.

Microscopic Simulation Model

Microscopic simulation engines simulate the movement, behavior, and decisions of individual drivers, based on models of car-following and lane-changing and a variety of population parameters. Typically, the analytical engine (which drives the simulation) begins by adding vehicles to the network at unconnected link entrances and at midblock locations (representing new trips from origins along that link). These new trips are generated according to a specified distribution (e.g., Poisson, Uniform), with the shape parameters for these distributions based on user-defined values and the trip tables provided to the simulation. Similarly, driver characteristics (e.g., driver aggressiveness, following distance, acceleration, or deceleration profile) are assigned for each vehicle at the time it first enters the simulation network according to statistical distributions. Each generated vehicle also is given a desired destination, and its progress toward that destination is simulated in small time increments (e.g., half a second) or “simulation steps.” Microscopic simulation models generally also consider roadway characteristics—including grade, lane width, and design speed—when evaluating the movement of individual vehicles on each link, with the effects of each roadway parameter being modeled according to relationships established by past research. Once a model is built, it must then be calibrated through the adjustment of driver and roadway parameters to achieve an optimal alignment between the route choices and link capacities observed in the model and measured in the field.

The microscopic simulation engine to be used for analysis of the I–15 ICM corridor is AIMSUN, developed by Transport Simulation Systems (TSS). This model currently is being used as part of the Decision Support System employed in the I–15 ICM system. This software suite is capable of simulating the details of ICM traffic control strategies, such as adaptive freeway ramp metering, arterial traffic signal coordination, and managed-use lane operations. At each step in the simulation, individual vehicles may be rerouted to different paths based on network conditions (e.g., congestion) and driver characteristics (e.g., driver willingness to divert, availability of traffic information to the driver). These routing decisions are based on the evaluated generalized costs (e.g., travel time) of each potential path to the traveler’s destination. Some drivers, designated as “informed,” will be assumed to have perfect knowledge of real-time travel information (by means of a smartphone, global positioning system (GPS) device, etc.), and will dynamically route themselves through the network based on the currently evaluated shortest time paths to their destinations. Other drivers who are not considered to have access to real-time travel information in the simulation will evaluate whether to divert to alternate routes in the face of heavy congestion based on historical travel-time information, which these drivers would have learned through experience.

In addition to modeling traveler choices and network conditions, the simulation also can inform appropriate actions to take in response to congestion. Because AIMSUN can realistically simulate the operation of various ICM components and the effects of changes to the network (e.g., lane blockages, real-time changes to speed limits), it can be used to evaluate the impacts of different operational decisions on congestion, bottleneck performance, or other metrics.

The traffic assignment method within AIMSUN allows the use of static and dynamic assignment methods based on requirements of different study types. Traffic assignment models are used to estimate the flow of traffic on a network. These models take as input a matrix of flows that indicate the volume of traffic between origin and destination (OD) pairs. The flows for each OD pair are loaded onto the network based on the travel time or impedance of the alternative paths that could carry this traffic. For traffic simulation models, the flow on a network is modeled by representing individual vehicle movements, and subsequently the link-based performance measures are evaluated based on movements of these individual vehicles as they rest in queues, travel in free flow, or maneuver through congestion. Whether all vehicles traveling a given path reach all links on the path within a given analysis period is dependent on time-variant travel conditions in the network. (Source: AIMSUN Microsimulator and Mesosimulator User’s Manual.)

The key behavioral assumptions underlying the User Equilibrium (UE) assignment model are that every traveler has perfect information concerning the attributes of network alternatives, all travelers choose a route that minimizes their travel time or travel costs, and all travelers have the same valuations of network attributes. At UE, no individual travelers can unilaterally reduce their travel time by changing paths. A consequence of the UE principle is that all used paths for an OD pair have the same minimum cost. An alternative and more realistic equilibrium model is known as Stochastic User Equilibrium or SUE. This model is premised on the assumption that travelers have imperfect information about network paths and/or vary in their perceptions of network attributes. At SUE, no travelers believe that they can increase their expected utility by choosing a different path. Because of variations in traveler perceptions and also in the level of service experienced, utilized paths do not necessarily have identical generalized costs. The SUE model is consistent with the concept of applying discrete choice models for the choice of route, but with the necessary aggregation and equilibrium solution.

Time of Departure

Microscopic simulation models require travel demand data in the form of origin/destination tables to properly generate and distribute (e.g., by mode, by route) trips on the network. These tables are generated on the macroscopic level by regional travel demand models and supplied as inputs to the microsimulation engine in AIMSUN. Generally, these regional models lack the temporal resolution to be suitable for use with microsimulation, with the macroscopic trip tables being aggregated into intervals of several hours each and the microscopic simulations requiring inputs on the order of 15-minute increments to achieve realistic and reasonable results. However, SANDAG has developed a travel demand model that produces trip tables in 15-minute intervals, making it suitable for use with AIMSUN’s microsimulation engine.

Modeling Integrated Corridor Management Strategies

Modeling ICM strategies is discussed in further detail in the ensuing sections. Based on observed BRT ridership it is not anticipated that there will be any significant mode shift activity as a result of ICM in the I–15 corridor.

Pretrip Traveler Information

Pretrip traveler information includes any travel information accessible to the public that can be used in planning trip routes, estimating departure times, and/or choosing travel mode. Such information can be available through the 511 system, via the phone, the Internet, or public access television. The analysis will capture the impacts of such information on traveler’s route choice and departure times. The fraction of I–15 users, who access such information prior to making their trip, will be estimated based on the Volpe Center survey findings and will be buttressed using data sources available in the region, such as available information on utilization of features like 511 and traffic Web sites in San Diego. Subsequently, this portion of the traveling population (the “informed travelers”) will be identified as a particular traveler class within the model.

En-Route Traveler Information

As part of the I–15 ICM system an enhanced 511 system is deployed in the region with predictive traveler information. AMS will analyze the impact of en-route information available to travelers on changes in route choice. Changes in route choice relate to real-time change in route choice of travelers based on travel time or congestion updates they receive via radio, 511, smart phones, or wireless-equipped GPS devices. This feature will be incorporated in the analysis as a fixed percentage of drivers who would be likely to have this information, along with a corresponding “compliance ratio” representing travelers who would consider changing route if faced with congestion.

To facilitate AMS of traveler responses to changeable message signs, modeling sensors will be coded in the model along the route upstream of the message sign. As drivers approach the message sign, they will pass through these sensors, which in turn will call up a macro that will update these drivers’ route choice decisions. When the macro is activated, new routes will be assigned to the percentage of drivers that divert their routes based on the posted information. Depending on the scenario or type of incident that may have occurred, compliance rates associated with each message sign will vary, and hence the amount of route diversion also will differ throughout the simulation runtime.

Signal Coordination on Arterials with Freeway Ramp Metering

In addition to simulating Signal Coordination on Arterials, which will involve implementing the QuicNet traffic signal control platform within the simulation model, the ramp metering algorithms will be introduced within this framework to evaluate the best possible strategy to optimize operations on both the freeway and the arterials. The Ramp Metering strategy will be coordinated with the signal timing set-up on the arterials, and the performance of both the corridor and impacted roadway network will be evaluated based on input from the QuicNet system. This will result in better coordination between ramp metering and arterial signals to better accommodate diversion.

Reduced Time of Detection, Notification, and Verification of Incidents

The analysis will evaluate the impacts of reducing time for detection, notification, and verification of incidents as part of the ICM deployment. With an active ICM deployment and improved coordination among agencies, the notification period can be shortened.

Table 1 lists the pre-deployment assumptions used in post deployment AMS. These model assumptions were based upon Evaluation Team and Volpe Center survey findings, local and regional agency feedbacks, transportation conditions, and expected traveler behavior.

Table 1. Post-deployment analysis, modeling, and simulation assumptions and inputs.

Outcome of Strategies	Summary/Notes to Modeling Team	Without ICM	With ICM in Place
1. Traveler Information			
1.1 Earlier dissemination of en-route incident and travel-time information	Because of quicker notification, en-route traveler information systems will disseminate incident information earlier to travelers. The effect is that more travelers will be able to alter routes, modes, and departure times. Incident duration stays the same with and without ICM.	On average 10 minutes to dissemination.	Faster dissemination (based on Evaluation team findings, reported for each day representing each cluster); and more travelers with traveler information and willing to make changes (based on Volpe survey findings).
1.2 Comparative travel times (mode and route)	Information dissemination (pretrip and en-route) will include travel-time comparisons for freeway, general purpose lanes, arterial, and transit. The effect is that more travelers will choose the best options to maintain consistent trip times.	General purpose lane and mainline travel time.	The decision choice is based on a generalized cost that feeds into a decision model. The effect is that as conditions worsen, more travelers will take more alternative options, including transit.
2. Improved Traffic Management			
2.1 Freeway ramp metering and signal coordination	Incident location-based strategy to coordinate arterial traffic signals with ramp meters.	None.	Better coordination between ramp metering and arterial signals to better accommodate diversion.
2.2 Ramp Metering	Post deployment AMS will analyze the conversion of the ramp metering algorithm from locally adaptive to corridor coordinated.	Local, occupancy-based algorithm—San Diego Ramp Metering Software (SDRMS).	Alternative ramp metering algorithms, as well as new signal timing plans, will be created and customized to fit a particular incident scenario.
3. Improved Incident Management			
3.1 Reduced time of detection, notification, and verification of incidents	Incident management system will be streamlined to provide coordination between Transportation Management Center/ California Department of Transportation (Caltrans) and FasTrak Customer Service Center/SANDAG. Clear-cut procedures and understanding of decisionmaking process and delegation of authority/responsibility of actions are expected to reduce response times.	All agencies notified within 30 to 60 minutes. Incident clearance in less than 90 minutes.	All agencies notified within 5 minutes.

Source: Cambridge Systematics, Inc.

Chapter 5. Performance Measures

This section provides an overview of the performance measures used in the Analysis, Modeling, and Simulation (AMS) of Integrated Corridor Management (ICM) strategies for the Interstate 15 (I–15) Corridor. The performance measures focus on the following key areas.

Mobility

Mobility describes how well the corridor moves people and freight. The mobility performance measures are readily forecast. Three primary types of measures were used to quantify mobility in the I–15 Corridor, including:

- **Travel time—**This is defined as the average travel time for the entire length of the corridor or segment within a study corridor by facility type (e.g., mainline, high-occupancy vehicle (HOV), and local street) and by direction of travel. Travel times are computed for the peak period.
- **Delay—**This is defined as the total observed travel time less the travel time under uncongested conditions, and is reported both in terms of vehicle-hours and person-hours of delay. Delays are calculated for freeway mainline and HOV facilities, transit, and surface streets.
- **Throughput—**Throughput is measured by comparing the total number of vehicles entering the network and reaching their destination within the simulation time period. The measure ensures that the throughput of the entire system can be utilized as a performance measure for all the scenarios. The corresponding Vehicle Miles Traveled (VMT), Person Miles of Travel (PMT), Vehicle Hours Traveled (VHT), and Person Hours Traveled (PHT) are reported as a macroscopic measure of the general mobility of the corridor.

Reliability and Variability of Travel Time

Reliability and variability capture the relative predictability of the public’s travel time. Unlike mobility, which measures how many people are moving at what rate, the reliability/variability measures focus on how much mobility varies from day to day. Appendix B of the final report titled, *Integrated Corridor Management Analysis, Modeling, and Simulation for the I–15 Corridor in San Diego, California*, describes the methodology that will be used in calculating reliability and variability impacts.

Emissions and Fuel Consumption

The I–15 Corridor AMS also will produce model outputs for use by the Evaluation Contractor to estimate emissions and fuel consumption, associated with the deployment of ICM strategies. The emissions analysis methodology will incorporate reference values to identify the emissions and fuel consumption rates based on variables, such as facility type, vehicle mix, and travel speed. Emissions will be computed by pollutant, mode, and facility type. Fuel consumption will be computed by fuel type, mode, and facility type.

Cost Estimation

For the identified ICM strategies the Evaluation Contractor will develop planning-level cost estimates for life-cycle costs (capital, operating, and maintenance costs). Costs will be expressed in terms of the net present value of various ICM components and are defined as follows:

- **Capital costs—**Include up-front costs necessary to procure and install intelligent transportation system (ITS) equipment. These costs are shown as a total (one-time) expenditure that includes the capital equipment costs, as well as the soft costs required for design and installation of the equipment.
- **Operations and Maintenance (O&M) costs—**Include those continuing costs necessary to operate and maintain the deployed equipment, including labor costs. While these costs do contain provisions for upkeep and replacement of minor components of the system, they do not contain provisions for wholesale replacement of the equipment when it reaches the end of its useful life. These O&M costs are presented as annual estimates.
- **Annualized costs—**Represent the average annual expenditure that would be expected in order to deploy, operate, and maintain the ICM improvement; and replace (or redeploy) the equipment as they reach the end of their useful life. Within this cost figure, the capital cost of the equipment is amortized over the anticipated life of each individual piece of equipment. This annualized figure is added with the reoccurring annual O&M cost to produce the annualized cost figure. This figure is particularly useful in estimating the long-term budgetary impacts of I–15 Corridor ICM deployments.

Within each of the capital, O&M, and annualized cost estimates, the costs are further disaggregated to show the infrastructure and incremental costs. These are defined as follows:

- **Infrastructure costs—**Include the basic “backbone” infrastructure equipment necessary to enable the system. For example, in order to deploy a camera surveillance system, certain infrastructure equipment must first be deployed at the traffic management center to support the roadside ITS elements. This may include costs, such as computer hardware/software, video monitors, and the labor to operate the system. Once this equipment is in place, however, multiple roadside elements may be integrated and linked to this backbone infrastructure without experiencing significant incremental costs (i.e., the equipment does not need to be redeployed every time a new camera is added to the system). These infrastructure costs typically include equipment and resources installed at the traffic management center, but may include some shared roadside elements as well.
- **Incremental costs—**Include the costs necessary to add one additional roadside element to the deployment. For example, the incremental costs for the camera surveillance example include the costs of purchasing and installing one additional camera. Other deployments may include incremental costs for multiple units. For instance, an emergency vehicle signal priority system would include incremental unit costs for each additional intersection and for each additional emergency vehicle that would be equipped as part of the deployment.

Structuring the cost data in this framework provides the ability to readily scale the cost estimates to the size of potential deployments. Infrastructure costs would be incurred for any new technology deployment. Incremental costs would be multiplied with the appropriate unit (e.g., number of intersections equipped, number of ramps equipped, number of Changeable message sign locations, etc.); and added to the infrastructure costs to determine the total estimated cost of the deployment.

The costs will be estimated for each scenario and a benefit/cost ratio will be assigned to all the individual performance measures. The annualized benefits for each of the measures mentioned above will be calculated using incident frequencies from the freeways and any arterial and transit incident information available.

Chapter 6. Guidance for Model Calibration

Accurate calibration is a necessary step for proper simulation modeling. Before modeling Integrated Corridor Management (ICM) strategies, model calibration ensures that base scenarios represent reality, creating confidence in the scenario comparison. Each simulation software program has a set of user-adjustable parameters that enable the practitioner to calibrate the software to better match specific local conditions. Calibration improves the ability of the model to accurately reproduce local traffic conditions. The key steps in model calibration include:

- Identification of necessary model calibration targets.
- Selection of the appropriate calibration parameter values to best match locally measured street, highway, freeway, and intersection capacities.
- Selection of the calibration parameter values that best reproduce current route choice patterns.
- Calibration of the overall model against overall system performance measures, such as travel time, delay, and queues.

Available data on bottleneck locations, traffic flows, and travel times will be used for calibrating the simulation model for the analysis of the Interstate 15 (I–15) Corridor. The I–15 Corridor calibration strategy will be based on the three-step strategy recommended in the Federal Highway Administration (FHWA) Guidelines for Applying Traffic Microsimulation Modeling Software. (Source: Dowling, R., A. Skabardonis, and V. Alexiadis, *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*, FHWA-HRT-04-040, Federal Highway Administration, July 2004.)

- **Capacity calibration.** An initial calibration is performed to identify the values for the capacity adjustment parameters that cause the model to best reproduce observed traffic capacities in the field. A global calibration is first performed, followed by link-specific fine tuning. The capacity calibration for the I–15 Corridor is performed utilizing volume data collected from the Caltrans Performance Measurement System (PeMS) database for the year 2003 between the periods of September to November.
- **Route choice calibration.** Because the I–15 Corridor includes parallel arterial streets, route choice calibration plays a significant role in the overall calibration effort. After capacity calibration, this second calibration process is performed with the route choice parameters. A global calibration is first performed, followed by link-specific fine tuning.
- **System performance calibration.** Finally, the overall model estimates of system performance (travel times and queues) is compared to the field measurements for travel times and queues. Fine-tuning adjustments are made to enable the model to better match the field measurements.

The calibration criteria presented in table 2 will be applied in all ICM analysis, modeling, and simulation (AMS).

Table 2. Model calibration criteria.

Calibration Criteria and Measures	Calibration Acceptance Targets
Traffic flows within 15 percent of observed volumes for links with peak-period volumes greater than 2,000 vehicles per hour (VPH).	For 85 percent of cases for links with peak-period volumes greater than 2,000 VPH.
Sum of all link flows	Within 5 percent of sum of all link counts
Travel times within 15 percent	>85 percent of cases
Visual Audits *Individual Link Speeds: Visually Acceptable Speed-Flow Relationship*	To analyst's satisfaction
Visual Audits *Bottlenecks: Visually Acceptable Queuing*	To analyst's satisfaction

Source: I–15 San Diego, California Analysis Plan, FHWA-JPO-10-039, p. 38.

For an incident day, the following criteria will be used within the context of the model calibration reasonableness assessment:

- **Freeway bottleneck locations.** Should be on a modeled segment that is consistent with the location, design, and attributes of the representative roadway section.
- **Duration of incident-related congestion.** Duration where observable within 25 percent.
- **Extent of queue propagation**. Should be within 20 percent.

Chapter 7. Analysis, Modeling, and Simulation Approach

Pre-Deployment analysis, modeling, and simulation (AMS) activities were associated with AMS support prior to the deployment and activation of Integrated Corridor Management (ICM) systems. Pre-Deployment AMS activities focused on the expected impacts and benefits of ICM associated with "as planned" ICM strategies prior to deployment. Pre-Deployment AMS activities were intended to both refine and prepare AMS capabilities to represent the "as planned" ICM strategies and to inform an ICM evaluation regarding the type, location, and intensity of potential benefits.

Post-Deployment AMS activities are intended to focus on the identifying impacts and benefits of the "as-deployed" ICM system. The "as-deployed" ICM strategies may differ from "as-planned" ICM strategies. The differences could include ICM strategies that are not successfully deployed, ICM strategies that are deployed differently from planned because of technical issues, and ICM strategies that are deployed differently to take advantage of enhancements or impacts not anticipated pre-deployment. Further, Post-Deployment AMS activities should take full advantage of site-specific traveler behavior and response characterization efforts conducted by the ICM Evaluation team. This includes the refinement of parameters and methods in tools to most accurately reflect traveler behavior in response to ICM strategies.

This chapter describes the post-deployment AMS activities that will support the ICM system for the Interstate 15 (I–15) corridor. During post-deployment AMS, the tools and methodologies developed in previous AMS efforts will be revisited and further evaluated in order to improve the capability of the site-specific tools to represent and evaluate the ICM system. The key objectives of post-deployment AMS include the following:

- Identify and facilitate further enhancements to tools, data, and methods developed from previous AMS activities.
- Conduct modeling analysis using enhanced tools in order to assess the impacts of the ICM strategies deployed in the corridor.
- Provide guidance for the site's ICM deployment and support for the integration of the AMS tools and methods developed with their ongoing corridor management practices.
- Support Demonstration Site-Specific ICM Demonstration Evaluation efforts.
- Manage the successful transition of modeling leadership responsibilities from the AMS contractor to the ICM Demonstration site staff and organizations.
- Provide technical documentation of ICM AMS tool development, data collection and analysis, model calibration and validation methods, and analytical methods deployed to both represent and evaluate ICM impacts.

To achieve these objectives, post-deployment AMS includes the following tasks in order to evaluate the impacts and readiness of the deployed ICM system. Subsequent sections provide further detail on each of the following tasks:

- Enhance tools to reflect as-deployed corridor management. Adjust tools and methods to differentiate the “as-deployed with-ICM” and “without-ICM” alternatives in analytical tools—this will be accomplished by modifying model inputs, assumptions, and analytical approaches to reflect as deployed ICM strategies and observed traffic conditions.
- Conduct post-deployment alternatives analysis. Support the ICM evaluation effort with a comprehensive assessment of ICM impacts considering external factors such as changes in gas prices potentially confounding a before and after ICM evaluation—these external factors can be modeled by modifying model inputs to reflect local gas prices.
- Preparation of post-deployment AMS assessment reports and related materials.

Enhance Tools to Reflect With-Integrated Corridor Management and Without-Integrated Corridor Management

This section describes the task items related to coordination and support of the alteration of tool inputs, analytical methodology, and enhancements to analytical software to reflect post-deployment corridor management technologies and strategies. The AMS Team will coordinate with San Diego Association of Governments (SANDAG) and the Evaluation Team to confirm, refine, and validate the parameters and assumptions that serve as the basis for modeling traveler responses and impacts related to ICM strategies currently present in the models used in the real-time decision support efforts. SANDAG and local stakeholders will review the model parameter assumptions to ensure that they sufficiently capture travel characteristics for the corridor and system response times according to the capabilities of their transportation management systems.

Post-deployment AMS work will capture the nature of the as-deployed system, including a good representation of traveler responses to ICM strategies, based on site-specific measurements of traveler responses and reactions, conducted in other parts of the ICM program. The AMS Team will coordinate with both the ICM Demonstration Site and the Evaluation Team to clearly identify if the deployed capability matches the assumptions made for modeling and simulation.

Analysis Tool for Post-Deployment Analysis, Modeling, and Simulation

Early in the AMS process, a decision was needed regarding whether to conduct AMS in: 1) the on-line simulation platform (AIMSUN) used in real-time decision support in the I–15 ICM and currently incorporated into the ICM management software, or 2) in the simulation platform used in pre-deployment AMS (TransModeler). Factors considered include:

- The AIMSUN model will need modifications to allow it to: 1) meet certain model validation benchmarks, 2) represent the full peak periods, instead of hourly traffic conditions, 3) conduct real-time mode shift analysis, and 4) conduct real-time analysis of parking demand and capacity. On the positive side the AIMSUN model: 1) includes all current ICM strategies already coded in the model; 2) has archived data associated with different operational conditions (incidents, high-demand, etc.); 3) is available for both the AM and PM peak periods; and 4) its use would ensure better consistency with the ICM evaluation effort as both efforts would rely on the same datasets.

- The TransModeler model already is calibrated but it uses 2003 data for its baseline (effects of the recent economic recession may not be properly accounted for), will still need to be made consistent with current travel demand and ICM deployment data, and focuses on the AM Peak only.

Upon discussion with the I–15 project team (including SANDAG and their partners and contractors) the AIMSUN platform was selected as the modeling tool to be used in post-deployment AMS.

Perform Post-Deployment Analysis, Modeling, and Simulation Tool Reasonableness Assessment

Full recalibration of the model system is not expected to be required in the Post-Deployment AMS Phase. However, a Reasonableness Assessment will be conducted in a similar manner to those conducted in the Pre-Deployment AMS Phase, where the model inputs and parameters were modified as necessary so that the model can reasonably match Post-Deployment field conditions, including location, extent, and severity of bottleneck locations.

If external factors impacting operational conditions in the corridor are significantly different post-ICM deployment (e.g., unusual weather patterns, dramatic changes in travel demand related to changed economic activity or fuel prices), which would require a level of effort beyond the envisioned Reasonableness Assessment here, then the AMS team will develop an analysis plan to mitigate the impact of these external factors in support of the ICM Demonstration Evaluation.

The Reasonableness Assessment Methodology involves the comparison of the I–15 model volumes and speeds (including bottleneck locations) with field observed data. In order to perform this assessment, the methodology includes four steps, as detailed in the following sections.

Step 1. Data Collection

The first step in the Reasonableness Assessment is to obtain the necessary data inputs, including field observed volumes and speeds along the freeway mainline and ramps of the I–15 Corridor, and arterials in the overall corridor area. Such data are being collected and archived as part of the ICM deployment on I–15 and as part of the evaluation effort.

Step 2. Reasonableness Assessment Criteria

The Reasonableness Assessment methodology will employ similar elements of the model calibration criteria detailed in the Federal Highway Administration (FHWA) Guidelines for Applying Traffic Microsimulation Modeling Software, including two types of data comparisons:

- **Volume comparison—**The first part of the assessment will determine whether the model reasonably replicates observed volume data both globally and for individual facilities. The criteria for comparing flows between model and observed values are summarized in table 3.

- **Travel speeds and bottlenecks—**The reasonableness of the model's speeds will be assessed based on a visual audit comparing speed contour diagrams from observed data with model speed data. Speed contour diagrams depict typical weekday speeds along the I–15 Corridor during the peak periods.

Table 3. Reasonableness Assessment criteria and acceptance targets for nonrecurrent congestion.

Criteria and Measures	Acceptance Targets
Hourly Flows, Model versus Observed	
Traffic flows within 15 percent of observed volumes for links with peak-period volumes greater than 2,000 vehicles per hour (VPH).	For 85 percent of cases for links with peak-period volumes greater than 2,000 VPH.
Sum of all link flows	Within 5 percent of sum of all link counts
Visual Audits	
Individual Link Speeds: Visually acceptable Speed-Flow relationships	To analyst's satisfaction
Bottlenecks: Visually Acceptable queuing	To analyst's satisfaction

Source: I–15 San Diego, California Analysis Plan, FHWA-JPO-10-039, p. 38.

Step 3. Model versus Observed Data Comparison

The third step of the Reasonableness Assessment will involve comparing the model outputs and performance measures against field volume and bottleneck data along the I–15 Corridor. The criteria established in step 2 will then be utilized to determine whether the model results adequately replicate the field data.

A preliminary assessment of the AIMSUN model's output reveals that the volume calibration criteria are met both by hour and globally. To fulfill the visual bottleneck audit criteria, the model output will be compared against the observed speed contours to assess whether the model output sufficiently replicates the temporal and geographical extents of bottlenecks along the corridor. Speed contour diagrams will be used to show that bottlenecks are occurring in approximately the same geographical location as on the field and that link speed-flow relationships, as well as queuing patterns appear to be reasonable in the model. These comparisons will be conducted for both the AM and PM peak periods, for both peak and offpeak directions, and for both a "typical day" and an incident day.

For the incident day, the following criteria will be used within the context of the model calibration reasonableness assessment:

- **Freeway bottleneck locations.** Should be on a modeled segment that is consistent with the location, design, and attributes of the representative roadway section.
- **Duration of incident-related congestion.** Duration where observable within 25 percent.
- **Extent of queue propagation**. Should be within 20 percent.

Step 4. Network and Demand Adjustments

If the model cannot replicate observed travel times and bottleneck characteristics, adjustments will be made to travel demand, supply, and other model parameters until the model reasonably replicates observed conditions.

Step 5. Summary of Results

The final step of the Reasonableness Assessment will be to summarize the methodology and results of the Reasonableness Assessment in a technical memorandum, in a draft and final version. The technical memorandum is titled "San Diego I–15—Post-Deployment Analysis, Modeling and Simulation (AMS) Reasonableness Assessment and Tool Modification Technical Memorandum—Final" and dated December 2015.

Collaboration with Volpe Center Traveler Survey and Integrated Corridor Management Evaluation Efforts

The Volpe Center has gathered behavioral data for travelers in the area of the I–15 ICM project through surveys. The ICM Evaluation team will be collecting and analyzing field data for the post-deployment period, and the AMS team will be modeling different operating scenarios (with and without ICM) using post-deployment data as well. Collaboration between efforts will be needed to ensure that any major events that occur on the corridor are properly captured/analyzed by all three. Furthermore, traveler information parameters and assumptions were collected by both the Volpe Center travel surveys and by the ICM evaluation effort.

Volpe survey measures needed for the AMS analysis include:

- Percent travelers who make a travel change based on pretrip information (percent of travelers who change time of departure, route, mode, destination, or decide not to make trip); and
- Percent travelers who make a change to their trip (en-route) based on information (percent of travelers who change route, mode, destination).

These measures were identified for comparable incidents in the pre- and post-ICM periods (and when a response plan was implemented in the post-ICM period).

Results from this analysis will be used to enhance the tools used in the post-deployment AMS, including: 1) "market penetration" (traveler awareness of unexpected congestion); 2) latency of traveler information arriving to a traveler; and 3) "compliance" (traveler will change route, time of travel) or for traveler information, including pretrip, en-route, and changeable message signs (CMS).

Other Model Enhancements

Additional model enhancements will be conducted as follows:

- **Ensure ICM System is Accurately Represented in the Model.** To more precisely model the operation of the ICM system and evaluate its benefits, SANDAG will provide the AMS team with the details of its decision support system (DSS) logic, including latest "triggers" and "thresholds" used in the actual operation of the system. Ramp metering and managed lane pricing algorithms also will become available through SANDAG. The AMS Team will conduct a detailed review of model assumptions and code elements to make sure the model accurately represents the implemented ICM system. As the I–15 ICM DSS currently is being fine-tuned some of its implementation details (such as triggers) may change in the course of system testing—any risk or uncertainty related to this "moving target" can be managed by focusing on actual events where the DSS was actually triggered and having the model replicate these observed conditions.

- **Model Represents the Full Peak Periods**. Currently, the AIMSUN model includes representations of hourly traffic conditions. The model will be enhanced to represent continuous peak periods for both AM and PM in both directions. This task involves: 1) "stitching" the two four-hour origin-destination matrices (representing AM and PM peak periods) from four individual hourly trip tables, 2) making sure that no travel demand is "lost," and 3) possibly extending the analysis period beyond the four-hour period until there is no severe congestion in the model.
- **Network Changes.** Three main types of changes will be made to the network for both offline and online use, including: a) **Geometric Changes,** including edits to intersections and new Direct Access Ramps; b) **Transit Updates,** including to bus routes or new bus services; and c) **Signal Updates** to make sure that any new signals or signals added to the Regional Arterial Management System are included.
- **Demand Changes.** The following steps will be involved with the update to the travel demands using more recent travel demand data. Step 1) Review and Update of Detection to account for the updates of the external systems. Step 2) New Data Collection to update the historical patterns for the Monday, Tuesday/Thursday, Wednesday, and Friday day types. Step 3) Creation of Patterns for the Different Day Types using various types of filtering mechanisms. Step 4) Creating and Training the Models. Step 5) Generation of Demand Matrices for Each Typical Day.
- **Postprocessors**. Currently the AIMSUN model does not have the ability to calculate impacts on the reliability of travel time, and includes internal processors to calculate impacts on vehicular emissions and fuel consumption based on European standards. The model will be enhanced so that it can calculate travel-time reliability impacts as well as produce estimates of emissions and fuel consumption impacts based on California standards for San Diego. The AMS team will provide postprocessors so it can produce inputs to the Evaluation Contractor's travel-time reliability impacts, as well as estimates of emissions and fuel consumption impacts.

Post-Deployment Alternatives Analysis

This section provides an overview of the AMS efforts associated with the Post-Deployment Alternatives Analysis. Once the models have been refined using the enhancements presented in the previous section, the models will be used for additional testing and analysis that will serve to assess the impacts of the implemented ICM deployment.

The potential ICM deployment-related alternatives will be identified through feedback and input of the site coordinators and local agencies. The alternatives analysis will serve to assess the performance of various components of the ICM system under different scenarios and events. The methodologies, tools, and strategies incorporated into the Post-Deployment Alternatives Analysis are documented in this section, including information regarding the alternative scenarios identified for analysis and the methodologies and the modeling efforts associated with each alternative scenario. The AMS team will focus on identifying and then representing the “as deployed” system. This includes linking the assumptions in section 4 about how the “with” and “without” cases are differentiated and modeled with the cluster analysis.

This AMS work will provide support to the San Diego ICM Demonstration site modeling team following the U.S. Department of Transportation (DOT)-approved Post-Deployment AMS Plan. Model runs conducted in this task will be performed primarily by staff from the ICM Demonstration Sites in conjunction with the AMS team.

An output will be an ICM Demonstration Site Post-Deployment AMS Interim Results Briefing. This briefing will provide relevant details on the progress of the AMS activities and insight into the capability of the modeling tools to differentiate pre- and post-deployment corridor management, and an assessment of the likelihood and nature of observable ICM deployment-related impacts. The briefing will convey all the necessary information from the AMS activities to the U.S. DOT with the intent of tailoring the information in the draft version to the intended audiences in the final version.

Analysis Timeframe

Although the ICM deployment on I–15 became operational in March 2013, a major update took place at the beginning of September 2013, and incident/event response capabilities came online in 2015. Wayfinder CMSs for route guidance on the arterials became active in 2015—these signs are expected to facilitate active routing in response to incident and events. Existing bus rapid transit (BRT) is operating during the peak periods only; in the summer of 2014 offpeak BRT became operational all day in both directions.

The period after the deployment and testing of Wayfinder CMS and additional BRT appears to be the best option for conducting AMS to represent “with ICM” because: 1) the basic ICM system will be operational for several months and any system bugs will be expected to have been identified and addressed, and 2) Wayfinder signs will have been deployed and active routing will be in place.

Cluster Analysis

A coordinated cluster analysis was conducted by the AMS and Evaluation teams that characterized different operational conditions in the I–15 corridor, as well as the frequency of occurrence of these conditions. Based on expected impact magnitude, proposed clusters of operational conditions were identified using the following variables:

- The day on which an incident or congestion event occurred.
- The time at which the incident or congestion event occurred (a.m., Midday, p.m.).
- The direction the traffic was traveling (North or South).
- The number of lanes that were closed during the incident or congestion event.
- The duration (in minutes) until the incident or congestion event was cleared.

- The flow of traffic that was traveling during the given time and direction.
- The average travel time in minutes.

Table 4 presents a summary of identified clusters for the I–15 corridor. Single incident/event delay impact is the difference of average travel time and the free flow travel time in the corridor. Total cluster delay impact for each cluster is calculated as the product of the single incident/event delay impact and number of days in the cluster. The right-most column shows the percent of days in a year that are represented in each cluster for each direction of travel and directional AM or PM peak period.

Table 4. Summary of all clusters for all time periods and both directions, ordered by largest impact.

Rank	Cluster	Duration (Min)	Volume (vph)	Travel Time (Min)	Single Incident Delay Impact (Min)	Incidents Per Period	Days in Cluster	Total Cluster Delay Impact (Min)	Percent of Total Analysis Time Period
1	SB AM 2	42.89	6,348	16.77	2.77	3.7	39	108.03	37.5%
2	NB PM 3	46.18	9,034	16.35	2.77	5.5	36	99.72	34.6%
3	NB MID 4	37.31	7,079	15.54	1.96	2.1	42	82.32	40.4%
4	NB PM 4	44.46	8,870	16.11	2.53	2.1	25	63.25	24.0%
5	SB AM 1	32.64	6,201	15.72	1.72	1.9	29	49.88	27.9%
6	NB PM 1	35.00	6,416	16.04	2.46	2.5	17	41.82	16.3%
7	SB PM 1	36.64	4,773	14.95	0.95	2.6	43	40.85	41.3%
8	SB MID 3	35.46	4,456	15.19	1.19	2.2	33	39.27	31.7%
9	NB AM 3	29.81	6,721	14.99	1.41	1.9	27	38.07	26.0%
10	SB AM 3	41.20	6,038	18.33	4.33	5.9	8	34.64	7.7%
11	SB MID 5	27.38	4,462	15.76	1.76	2.4	19	33.44	18.3%
12	NB MID 3	32.29	5,992	16.29	2.71	1.6	12	32.52	11.5%
13	NB AM 1	34.17	4,767	15.02	1.44	1.7	19	27.36	18.3%
14	SB AM 9	50.40	5,658	21.81	7.81	9.7	3	23.43	2.9%
15	NB PM 2	32.53	6,955	16.5	2.92	8.8	8	23.36	7.7%
16	NB AM 4	23.55	5,657	15.94	2.36	3.6	9	21.24	8.7%
17	SB PM 3	29.97	5,011	15.17	1.17	3.1	18	21.06	17.3%
18	NB PM 5	34.71	6,836	19.83	6.25	4.7	3	18.75	2.9%
19	SB MID 1	32.88	4,847	15.41	1.41	3.9	13	18.33	12.5%
20	SB AM 4	46.01	6,154	16.91	2.91	10.6	5	14.55	4.8%
21	NB AM 2	35.13	6,937	15.09	1.51	6.0	9	13.59	8.7%
22	NB MID 6	30.90	5,903	16.24	2.66	7.4	5	13.30	4.8%
23	NB MID 2	38.14	5,148	15.77	2.19	4.5	6	13.14	5.8%

Table 4. Summary of all clusters for all time periods and both directions, ordered by largest impact (continuation).

Rank	Cluster	Duration (Min)	Volume (vph)	Travel Time (Min)	Single Incident Delay Impact (Min)	Incidents Per Period	Days in Cluster	Total Cluster Delay Impact (Min)	Percent of Total Analysis Time Period
24	SB MID 6	51.14	4,354	16.06	2.06	6.2	6	12.36	5.8%
25	SB PM 2	26.60	5,409	15.08	1.08	3.2	11	11.88	10.6%
26	NB PM 8	51.29	6,178	24.05	10.47	7.0	1	10.47	1.0%
27	NB AM 5	68.75	8,146	15.52	1.94	2.0	5	9.70	4.8%
28	NB MID 7	30.85	7,565	15.5	1.92	5.6	5	9.60	4.8%
29	NB MID 1	48.53	4,753	15.49	1.91	2.0	5	9.55	4.8%
30	SB MID 2	36.86	4,177	15.57	1.57	1.8	6	9.42	5.8%
31	NB PM 6	38.05	9,156	18.02	4.44	13.0	2	8.88	1.9%
32	SB PM 5	61.17	4,711	16.17	2.17	2.0	4	8.68	3.8%
33	NB MID 5	38.38	5,888	15.23	1.65	1.3	4	6.60	3.8%
34	SB MID 4	30.84	4,481	15.74	1.74	11.0	3	5.22	2.9%
35	SB PM 4	61.68	4,788	15.21	1.21	9.5	4	4.84	3.8%
36	SB MID 9	22.17	4,999	15.42	1.42	1.3	3	4.26	2.9%
37	SB PM 6	39.00	4,888	16.13	2.13	8.0	2	4.26	1.9%
38	NB AM 6	113.38	6,208	15.69	2.11	4.5	2	4.22	1.9%
39	SB AM 7	35.44	4,774	15.30	1.30	1.7	3	3.90	2.9%
40	NB MID 8	262.83	7,042	15.48	1.90	2.0	2	3.80	1.9%
41	SB PM 7	693.80	4,662	17.17	3.17	10.0	1	3.17	1.0%
42	NB AM 7	52.65	4,453	16.62	3.04	17.0	1	3.04	1.0%
43	SB MID 12	27.73	5,193	15.45	1.45	6.0	2	2.90	1.9%
44	NB PM 7	733.25	7,778	16.45	2.87	4.0	1	2.87	1.0%
45	NB MID 9	659.00	6,507	16.33	2.75	4.0	1	2.75	1.0%
46	SB MID 8	31.00	5,239	14.86	0.86	1.7	3	2.58	2.9%
47	SB AM 6	229.00	6,350	16.52	2.52	1.0	1	2.52	1.0%
48	SB PM 9	210.00	5,153	15.24	1.24	1.0	2	2.48	1.9%
49	NB AM 8	34.75	1,880	15.95	2.37	8.0	1	2.37	1.0%
50	SB AM 8	32.25	3,417	15.14	1.14	1.5	2	2.28	1.9%
51	SB MID 10	753.33	4,397	15.88	1.88	3.0	1	1.88	1.0%
52	SB AM 5	804.00	6,314	15.70	1.70	1.0	1	1.70	1.0%
53	SB MID 11	203.00	4,651	15.55	1.55	1.0	1	1.55	1.0%

Table 4. Summary of all clusters for all time periods and both directions, ordered by largest impact (continuation).

Rank	Cluster	Duration (Min)	Volume (vph)	Travel Time (Min)	Single Incident Delay Impact (Min)	Incidents Per Period	Days in Cluster	Total Cluster Delay Impact (Min)	Percent of Total Analysis Time Period
54	SB MID 7	194.29	4,415	15.43	1.43	7.0	1	1.43	1.0%
55	NB AM 9	184.00	5,723	14.92	1.34	1.0	1	1.34	1.0%
56	NB PM 9	189.00	4,620	14.77	1.19	1.0	1	1.19	1.0%
57	SB PM 8	274.47	5,280	14.95	0.95	15.0	1	0.95	1.0%

Source: ICM Evaluation—San Diego Site Cluster Analysis—Daily Incident Probability, Battelle, 4/14/16, p. 9-10, unpublished.

The most impactful clusters of operational conditions will be analyzed using the AMS tools and then compared to the “do nothing” alternatives representing the transportation system without ICM turned on (but with pre-ICM corridor management practices in place). These comparisons will facilitate the evaluation of impacts of the ICM system on the I–15 corridor. The identification of specific incidents or other events representing individual clusters will be closely coordinated between the AMS, Evaluation and Volpe Center survey teams so as to ensure that event start and end times, impacts (such as number of lanes closed), and other characteristics are in complete agreement between the AMS, Evaluation and Survey team efforts. For each one of the most impactful and frequent clusters a representative day with an incident and/or a congestion event and an ICM response plan was selected for AMS shown in table 5.

Table 5. Summary of representative days/incidents in the most frequent/impactful clusters during the AM and PM peak periods.

#	Baseline Cluster by Direction and Time Period	Information from Baseline Cluster Analysis: Days in Cluster	Information from Baseline Cluster Analysis: Total Cluster Day Impact (min.)	Information from Baseline Cluster Analysis: Percent of Total Analysis Time Period	Baseline Period Date	Post-Deployment Period: Date	Post-Deployment Period: DSS Event ID	Post-Deployment Period: DSS Pan Type Implemented	Post-Deployment Period: DSS Response ID
1	NB PM 4	25	63.25	24.0	10/12/12	7/7/14	639956	Ramps, Signals, ATIS	19536
2	SB AM 2	39	108.03	37.5	10/2/12	2/9/15	754666	Signals, ATIS	27929
3	NB PM 5	3	18.75	2.9	11/21/12	2/19/15	760369	Signals, ATIS	28292
4	SB AM 3	8	34.64	7.7	10/1/12	5/7/15	804238	Ramps, Signals, ATIS	30028
5	n/a, hypothetical	–	–	–	–	5/26/15		None. Managed lanes opened.	
6	SB AM 1	29	49.88	27.9	1/30/13	5/27/15	817649	Signals	30332
7	NB PM 2	8	23.36	7.7	1/15/13	6/9/15	842085	Ramps, Signals	30451
8	NB PM 1	17	41.82	16.3	1/28/13	6/16/15	845922	Ramps, Signals, ATIS	30617
9	NB PM 3b	36	99.72	34.6	1/30/13	5/5/14	853963	Ramps, Signals, ATIS	31039

Source: ICM Evaluation—San Diego Incident Matching, Battelle, 4/14/16, p. 5, unpublished.

Incident and congestion event matches with response plans implemented were identified for eight clusters with a fairly high frequency of occurrence as shown in table 5. These incident and congestion event matches represent a variety of response plans and clusters. One additional hypothetical scenario was identified for AMS, including a ninth scenario to examine the potential benefit of opening the managed lanes to all traffic during a major incident. An incident that warrants a response was selected that occurred and its duration and number of lanes closed was similar to the average incident that warranted a response.

Analysis Approach

The I–15 ICM system is activated during incidents and other nonrecurrent events such as occurrence of high travel demand in the corridor. Incidents and other noncongestion events are the most frequent causes of nonrecurrent congestion in the corridor, and their frequency of occurrence and impact was documented using ICM archived data; based on these data, incidents and congestion events were matched with representative days for each of the 10 clusters described in the previous chapter. Each representative day will be modeled with the ICM response plan activated during the incident, and without the ICM response plan. Also, each representative day will include in addition to the primary incident any other incidents that may have occurred during that day; if the nonprimary incidents are reported as having “zero lanes blocked,” the capacity at the adjacent freeway lane will be reduced by a percentage consistent with a “blocked shoulder” in the Highway Capacity Manual. The difference between the “with ICM” and “without ICM” model runs will represent the impact of ICM for the operational condition represented by the particular cluster. The sum of all impacts across the top nine clusters shown in table 5 will represent the majority of impacts associated with the implementation of ICM in the I–15 corridor.

An iterative travel demand adjustment process will be employed at the start of the analysis of each of the cluster-representative days, so that the model reasonably represents the travel demand during each particular representative day. This process will start by comparing observed versus modeled link volumes in the five links directly upstream of the primary incident during that day. Then the origin-destination table will be iteratively adjusted so that the sum of the modeled volumes in these links will come to within 15 percent of the sum of the observed volumes in these links. The resulting trip table will then be used in modeling both the “with ICM” and “without ICM” scenarios.

Based on the Volpe Center traveler surveys, table 6 presents parameters that will be used in the AMS related to the travelers’ awareness, use, and compliance to traveler information:

- “Awareness” represents the portion of travelers who have access to information.
- “Use” represents a traveler’s intent to take action, but does not necessarily result in an action, unless the proposed mode-route option is more attractive than the “historical route,” based on the model’s diversion rules. Therefore, “use” reflects an upper bound on the percent of travelers who might divert as a response to the information, with the actual percentage dependent on the attractiveness of the new route and referred to as “Compliance.” For better linearity of model functions (nonjumpiness across steps) the model uses this convention, where “compliance” = “awareness” * “use.”
- This AMS effort (as reported in table 6) will use the compliance numbers reported in the pulse summary tables provided by the Volpe Center on 6/15/2015. These are the combined compliance numbers across AM and PM pretrip and en route, unweighted.
- For awareness the AMS will use the percentages from the Volpe Center’s baseline/endline surveys, and they are both in the mid-80 to mid-90 percent range.

Table 6. San Diego I–15 integrated corridor management corridor—traveler information parameters used in analysis, modeling, and simulation (Percent).

	Pretrip			En-Route		
	Awareness	Use	Compliance	Awareness	Use	Compliance
Pre ICM	93.00	8.19	7.62	83.00	12.29	10.20
Post ICM	93.00	8.59	7.99	84.00	12.64	10.62

Source: Integrated Corridor Management Initiative: Traveler Response Panel Survey San Diego—Draft, Volpe Center, 7/11/16.

Table 7 shows the analysis settings for conducting Post-Deployment AMS for the San Diego I–15 corridor.

Table 7. San Diego I–15 integrated corridor management corridor—summary of post-deployment analysis settings.

Parameter	Value	Comment
Analysis year	2015	The analysis year was derived from the anticipated completion of design, testing, and deployment of ICM.
Time period of analysis	AM peak period (6 a.m. to 10 a.m.) PM peak period (3 p.m. to 7 p.m.)	Several incidents and congestion events that occurred in days representative of different clusters, and for which response plans were activated were selected to represent AM and PM peak periods. Also, one hypothetical scenario was selected for analysis, including opening all managed lanes to all traffic during a major incident.
Simulation period	4 hours in each peak period	6 to 10 a.m. and 3 to 7 p.m. were selected to represent the AM and PM analysis periods.
Freeway incident locations and durations	Based on cluster analysis and presented in table 5	These locations experienced incidents, offered the potential for route diversion, had a response plan activated, and had a high impact on corridor travel.

Source: Cambridge Systematics, Inc.

The AMS effort will produce performance measures for travel time, delay, throughput, vehicle- and person-hours of travel, vehicle- and person-miles of travel, and travel time reliability for the entire I–15 corridor area or segment within the corridor by peak period, by facility type (e.g., mainline, frontage road, and local street), by mode, and by direction of travel. The I–15 Corridor AMS also will produce model outputs for use by the Evaluation Contractor to estimate emissions and fuel consumption, associated with the deployment of ICM strategies. The data provided to the Evaluation Contractor will include a) link lengths, link characterization (freeway, major arterial, frontage road, minor arterial) and average grade for all network links, and b) average hourly directional link volumes and speeds for the I–15 freeway, other strategic and relevant north-south arterials, and arterial links connecting the I–15 freeway to potential diversion routes. The emissions analysis methodology will incorporate reference values to identify the emissions and fuel consumption rates based on variables, such as facility type, vehicle mix, and travel speed. The emissions and fuel consumption rates will be based on available sources. Emissions will be computed by pollutant, mode, and facility type. Fuel consumption will be computed by fuel type, mode, and facility type.

Post-Deployment Analysis, Modeling, and Simulation Assessment Report and Related Materials

The results of this work will be a draft ICM Demonstration Site Post-Deployment Assessment Report, detailing the approach, results, and lessons learned. The Assessment Report will include both an Executive Summary suitable for decisionmakers and detailed technical documentation suitable for AMS practitioners.

The Executive Summary and the Assessment Report will provide the following:

- Description of the context of AMS within the ICM program to orient an unfamiliar audience.
- Explanation of the key roles of AMS in the ICM Program, including a description of the following:
    - Developing methodologies that support the process for continuous improvement.
    - Identifying when and where ICM strategies will be the most beneficial.
    - Supporting the ICM evaluation.
    - Developing the analytical capital within each site so that the analyses can be conducted on a regular basis to support ICM decisionmaking (either in planning mode or Decision Support System mode).
- Explanation of the AMS process i.e., “what was done,” the “how it was done.”
- Articulation of results in terms of benefits, particularly on days with high-demand and a major incident.
- Explanation of caveats for credibility regarding the calibration, validation, and methodology.
- Specific lessons learned in the AMS, including specific examples such as:
    - A well-documented Analysis Plan provided value with the sites to refine the details of their strategies and how they are expected to be deployed.
    - The operational conditions analysis combined with the strategy refinement were critical outcomes of the AMS effort even if the models had never been run.

The detailed technical documentation portion of the Assessment Report will provide explanation of the following:

- ICM AMS tool development.
- Data collection and analysis.
- Model calibration and validation methods.
- Analytical methods deployed to both represent and evaluate ICM impacts.

This work will include an ICM Demonstration Site Post-Deployment Assessment Briefing—including a short version and a long version, both of which will cover the Dallas and San Diego Demonstration Sites together. Both versions of the electronic presentations will detail the approach, results, and lessons learned, but the versions will differ in the intended audience. The short version will be used for conference presentations to audience of decisionmakers, where the focus would be on purpose, process, results, and lessons learned. The long version will be used for webinars and possibly workshops to cover an audience of AMS practitioners, where the instruction will explain the process, results, lessons learned, and recommended practice.

The AMS Team will document the results of the modeling analyses and providing summary graphics, tables, and explanatory text for the incorporation of modeling results into an overall evaluation report, in coordination with the Evaluation Contractor.

The AMS team also will provide to the U.S. DOT the electronic files and data used for conducting the analysis, modeling, and simulation of the ICM Demonstration Sites. The AMS team will deliver required data and tools (excluding vendor-licensed software) to support U.S. DOT efforts to replicate ICM analyses and visualize ICM impacts in a designated Federal facility.

Chapter 8. Schedule and Allocation of Responsibilities

This section provides a summary of work plan tasks and subtasks, deliverables, lead responsibility, and schedule associated with Post-Deployment Analysis, Modeling, and Simulation (AMS), as shown in table 8. The Post-Deployment AMS efforts will be a collaborative effort between Cambridge Systematics (Integrated Corridor Management (ICM) AMS Contractor), San Diego Association of Governments (SANDAG), including SANDAG's team, and Battelle (ICM Evaluation contractor). Table 8 describes the division of responsibilities and each agency's role for each of the AMS tasks. Table 9 presents key coordination points between the ICM AMS, Evaluation, Sites, and Volpe Center efforts.

Table 8. Post-Deployment Analysis, Modeling, and Simulation—schedule and allocation of responsibilities.

No.	Task and Work Plan Items	Deliverables	Responsibility (Lead in Boldface)	Completion Date
1	**Project Management and Program Support**			
	1. Kickoff meeting in San Diego	Meeting minutes	FHWA, **CS,** Volpe Center Battelle, TSS, SANDAG	Sept 13, 2013
5.7	**San Diego Post-Deployment AMS Plan**			
	1. Development of draft Analysis Plan	Analysis Plan Draft	**CS**	January 31, 2014 Resubmit in early February 2016
	2. Review of Analysis Plan	Comments due	**FHWA,** SANDAG, Volpe Center, Battelle	February 28, 2016
	3. Respond to comments	Revised Analysis Plan	**CS**	March 15, 2016
	4. Final Analysis Plans/Approvals	Final Analysis Plan	**CS/**FHWA	March 30, 2016
	5. Site visits		**CS,** FHWA	November 7/8, 2013
5.8	**Enhance Tools to Reflect Post-Deployment Conditions**			
	1. Select analysis tool		**CS,** SANDAG	December 31, 2013
	2. AMS tool reasonableness assessment	Draft Technical Memorandum	**CS,** SANDAG	November 15, 2015
	3. Collaboration with Volpe Center survey and ICM evaluation		CS, Volpe Center, Battelle	Ongoing
	4. Model Enhancements	Draft Technical Memorandum	**CS,** SANDAG	December 15, 2015
	5. Review of Technical Memoranda	Comments due	**FHWA,** SANDAG	November 30, 2015
	6. Respond to comments and produce final versions of Technical Memoranda	Revised memoranda	**CS,** SANDAG	December 28, 2015
	7. Implement modifications in model	Final baseline models	SANDAG, **CS**	January 30, 2016
5.9	**Post-Deployment Alternatives Analysis**			
	1. Establish alternatives analysis scenarios	Part of Analysis Plan	**CS,** SANDAG	March 30, 2016
	2. Post-deployment model runs and postprocessor results	Post processor results and documentation of impacts	**CS**	May 29, 2016
	3. Submit draft San Diego ICM Post-Deployment Interim Results Briefing for comments	Draft briefing	**CS,** SANDAG	June 27, 2016
	4. Review of draft Interim Results Briefing	Comments due	**FHWA,** SANDAG, Volpe Center, Battelle	July 11, 2016

CS = Cambridge Systematics, Inc.; FHWA = Federal Highway Administration; SANDAG = San Diego Association of Governments

Table 8. Post-Deployment Analysis, Modeling, and Simulation—schedule and allocation of responsibilities (continuation).

No.	Task and Work Plan Items	Deliverables	Responsibility (Lead in Boldface)	Completion Date
5.9	**Post-Deployment Alternatives Analysis (continuation)**			
	5. Respond to comments and prepare final Interim Results Briefing	Final Assessment Briefing	CS	**July 31, 2016**
5.10	**ICM Post-Deployment Assessment Report and Related Materials**			
	1. Submit draft ICM Demonstration Site Post-Deployment Assessment Report for comments	Draft Post-Deployment Assessment Reports	**CS**	Aug 15, 2016
	2. Review of draft Assessment Report	Comments due	**FHWA,** SANDAG, Volpe Center, Battelle	September 1, 2016
	3. Respond to comments and prepare Final Assessment Report	Final Assessment Reports	**CS**	September 16, 2016
	4. Submit draft ICM Demonstration Site Post-Deployment Assessment Briefing for comments	Draft Post-Deployment Assessment Briefing	**CS**	September 1, 2016
	5. Review of draft Assessment Briefing	Comments due	**FHWA,** SANDAG, Volpe Center, Battelle	September 15, 2016
	6. Respond to comments and prepare final Assessment Briefing	Final Assessment Briefing	**CS**	September 30, 2016
	7. Presentation of Post-Deployment Assessment Briefing	Presentation	**CS**	October 14, 2016
	8. Results of the modeling analysis for incorporation into the overall evaluation report	Evaluation Report Technical Memorandum	**CS,** SANDAG	July 31, 2016
	9. Electronic files, data and tools used for conducting the post-deployment AMS of I–15 ICM	Files, data and tools	**CS,** SANDAG	October 28, 2016
	13. Submit draft ICM Demonstration Site Post-Deployment Summary Briefing	Draft Post-Deployment Summary Briefing	**CS**	Dec 2, 2016
	14. Review of draft Summary Briefing	Comments due	**FHWA,** Volpe Center, Battelle	Dec 16, 2016
	15. Respond to comments and prepare final Summary Briefing	Final Summary Briefings	**CS**	Dec 30, 2016

CS = Cambridge Systematics, Inc.; FHWA = Federal Highway Administration; SANDAG = San Diego Association of Governments

Source: Cambridge Systematics, Inc.

Table 9. Key points of integrated corridor management coordination related to analysis, modeling, and simulation.

General Topic	Subtopic	Text Descriptions/"Process Input"	Evaluation Plan/Observed Data *(Evaluation team (Battelle))*	Modeling Plan *(AMS team (Cambridge Systematics, Inc.))*
No-ICM Alternative System Management "How we used to do it"	Traffic Signal Control Capabilities	***(Sites)*** • base plans and settings by time of day • adaptation triggers and alternative plans • adaptation: where possible, when, time to implement	FOR EACH ITEM, how well differentiated in time-series data, quantify some of aspects of system management, e.g., measured time-to-implement	FOR EACH ITEM, how well can the selected model(s) represent this aspect of systems management, and what enhancements (if any) can be considered to improve this representation
	Traveler Information Capabilities	***(Sites)*** • base messaging and continuous features • triggers and alternative messages (if any) • info scope, precision and update cycle • pretrip versus en route considerations		
	Ramp Metering	***(Sites)*** • base plans and settings by time of day • adaptation triggers and alternative plans • adaptation: where possible, when, time to implement		
	Incident Management	***(Sites)*** • response triggers and response descriptions • adaptation: where possible, when, time to implement		
With-ICM Alternative System Management "How we do it now or will do it"	Traffic Signal Control Capabilities	***(Sites)*** • base plans and settings by time of day • adaptation triggers and alternative plans • adaptation: where possible, when, time to implement	FOR EACH ITEM, how well differentiated in time-series data, quantify some of aspects of system management, e.g., measured time-to-implement	FOR EACH ITEM, how well can the selected model(s) represent this aspect of systems management, and what enhancements (if any) can be considered to improve this representation
	Traveler Information Capabilities	***(Sites)*** • base messaging and continuous features • triggers and alternative messages (if any) • info scope, precision and update cycle • pretrip versus en route considerations		

Table 9. Key points of integrated corridor management coordination related to analysis, modeling, and simulation (continuation).

General Topic	**Subtopic**	**Text Descriptions/"Process Input"**	**Evaluation Plan/Observed Data *(Evaluation team (Battelle))***	**Modeling Plan *(AMS Team (Cambridge Systematics, Inc.))***
	Ramp Metering	***(Sites)*** • base plans and settings by time of day • adaptation triggers and alternative plans • adaptation: where possible, when, time to implement		
	Incident Management	***(Sites)*** • response triggers and response descriptions • adaptation: where possible, when, time to implement		
Operational Conditions and Playbook		***(Sites)*** • under condition X, we adapt in the following ways, until some future time, when there is a return to base control settings	Determine the set of [X] operational conditions, including frequency of occurrence. Where are there comparable with/without cases in the observed data? What other cases are needed from modeling?	Identifies the set of modeling runs to be conducted, specific conditions [X1, X2, X3…] and the two alternative actions in each case (no-ICM and with-ICM)
Traveler Behavior	Survey	***(Sites)*** • information utilization rates • decisionmaking (possibly different with/without) • disaggregate models of traveler behavior	Observed diversion rates and conditions on days where behavior is modeled	Describe how well represented and what enhancements (if any) can be considered to improve behavioral modeling, plan validation of incident cases using observed data
Performance Measurement	Measures	• National Guidance	Define key measures derived from observed data	Define key measures derived from simulation data, as consistent as possible with those from observed data
	Assumptions		Set out-year assumptions on demand changes, timeframe of C/B analysis, value of time	Utilize consistent out-year assumptions on demand changes, timeframe of C/B analysis, value of time

(Source: Karl Wunderlich, Noblis.)

References

- Alexiadis, V. and A. Armstrong, *Integrated Corridor Management Modeling Results Report: Dallas, Minneapolis, and San Diego*. No. FHWA-JPO-12-037. 2012.
- Dowling, R., A. Skabardonis, and V. Alexiadis, *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*, U.S. DOT-HRT-04-040, Federal Highway Administration. July 2004.
- Papayannoulis, Vassilis, et al. *Integrated Corridor Management: I–15 San Diego, California Analysis Plan*. No. FHWA-JPO-10-039. 2010.

Appendix A. List of Acronyms

AMS	Analysis, Modeling, and Simulation
BRT	Bus Rapid Transit
CMS	Changeable Message Sign
DOT	Department of Transportation
DSS	Decision Support System
FHWA	Federal Highway Administration
GPS	Global Positioning System
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
I–15	Interstate 15
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
ITS	Intelligent Transportation Systems
NB	Northbound
OD	Origin-Destination
O&M	Operations & Maintenance
PeMS	Performance Measures System
PHT	Person Hours Traveled
PMT	Person Miles Traveled
SANDAG	San Diego Association of Governments
SB	Southbound
SDRMS	San Diego Ramp Metering Software
SR	State Route
SUE	Stochastic User Equilibrium
TDM	Travel Demand Model
TSS	Transport Simulation Systems
UE	User Equilibrium
VHT	Vehicle Hours Traveled
VMT	Vehicle Miles Traveled
VPH	Vehicles Per Hour

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