Integrated Corridor Management Initiative: Demonstration Phase Evaluation

San Diego Decision Support System Analysis Test Plan

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Final Report — August 21, 2012
Publication Number FHWA-JPO-13-050

U.S. Department of Transportation

Produced by Integrated Corridor Management Initiative: Demonstration Phase Evaluation
U.S. Department of Transportation
Research and Innovative Technology Administration
Federal Highway Administration
Federal Transit Administration

Notice

Technical Report Documentation Page

1. Report No. FHWA-JPO-13-050	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Integrated Corridor Management Initiative: Demonstration Phase Evaluation – San Diego Decision Support System Analysis Test Plan		5. Report Date August 21, 2012 6. Performing Organization Code
7. Author(s) Matthew Lee, URS Michael Pack, UMD		8. Performing Organization Report No.
9. Performing Organization Name and Address Battelle 505 King Avenue Columbus, OH 43201		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-06-D-00007/ T.O. BA07081
12. Sponsoring Agency Name and Address U.S. Department of Transportation Research and Innovative Technology Administration Federal Highway Administration Federal Transit Administration 1200 New Jersey Avenue, S.E. Washington, DC 20590		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

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

17. Key Word Integrated Corridor Management, ICM, evaluation, test plan		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 50	22. Price

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

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ACKNOWLEDGEMENTS

Many individuals from the San Diego site team provided crucial input to the development of this test plan. We acknowledge and appreciate the assistance provided by U.S. DOT and the local partners in San Diego, particularly Mr. Alex Estrella, Mr. Peter Thompson, and Mrs. Carolyn Alkire of the San Diego Association of Governments (SANDAG) and Mr. Mike Washkowiak and Mr. Derek Toups (Kimley-Horn).

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LIST OF ABBREVIATIONS

AMS	Analysis, Modeling and Simulation
CHP	California Highway Patrol
DMS	Dynamic Message Sign
DSS	Decision Support Systems
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GUI	Graphical User Interface
HOT	High-Occupancy Tolling
HOV	High-Occupancy Vehicle
HTTP	Hypertext Transfer Protocol
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
IMTMS	Intermodal Transportation Management System
I-15	Interstate-15
iNET	Intelligent NETworks
ITS	Intelligent Transportation Systems
KTT	Knowledge and Technology Transfer
LRT	Light Rail Transit
MOE	Measure of Effectiveness
MTS	Metropolitan Transit System
NCTD	North County Transit District
NWS	National Weather Service
OES	Office of Emergency Services

PDT	Project Development Team
PeMS	Performance Measurement System
RITA	Research and Innovative Technology Administration
R/T	Real-time
SANDAG	San Diego Association of Governments
SD SAFE	San Diego County Service Authority for Freeway Emergencies
S.R.	State Route
TMDD	Traffic Management Data Dictionary
UMD	University of Maryland
U.S. DOT	U.S. Department of Transportation
VMT	Vehicle-Miles Travelled
Volpe Center	John A. Volpe National Transportation System Center

1.0 INTRODUCTION

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

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

This test plan is focused on evaluating the impact and effectiveness of the Decision-Support (DSS) System, a central component of the ICM demonstration in San Diego. The DSS acts as the brain behind the ICM system, fusing data from different sources into a common format, analyzing the current and projected conditions of the system, and providing a response plan to operators, which when implemented could potentially improve overall corridor performance.

The remainder of this introduction chapter describes the ICM program and elaborates on the hypotheses and objectives for the demonstration phase deployment in Dallas and San Diego, as well as the subsequent evaluation analyses. The remainder of the report is divided into five sections. Chapter 2 summarizes the Decision Support System Analysis overall. Chapters 3 and 4 describe the quantitative and qualitative data that will be used in this analysis. Chapter 5 describes how the data will be analyzed. Chapter 6 presents the risks and mitigations associated with Decision Support System data.

1.1 ICM Program[1]

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

ICM enables transportation managers to optimize use of all available multimodal infrastructure by directing travelers to underutilized capacity in a transportation corridor—rather than taking the more traditional approach of managing individual assets. Strategies include motorists

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

shifting their trip departure times, routes, or modal choices, or transportation managers dynamically adjusting capacity by changing metering rates at entrance ramps or adjusting traffic signal timing plans to accommodate demand fluctuations. In an ICM corridor, travelers can shift to transportation alternatives—even during the course of their trips—in response to changing traffic conditions.

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

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

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

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

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

1.2 ICM Demonstration Phase Deployments[2]

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

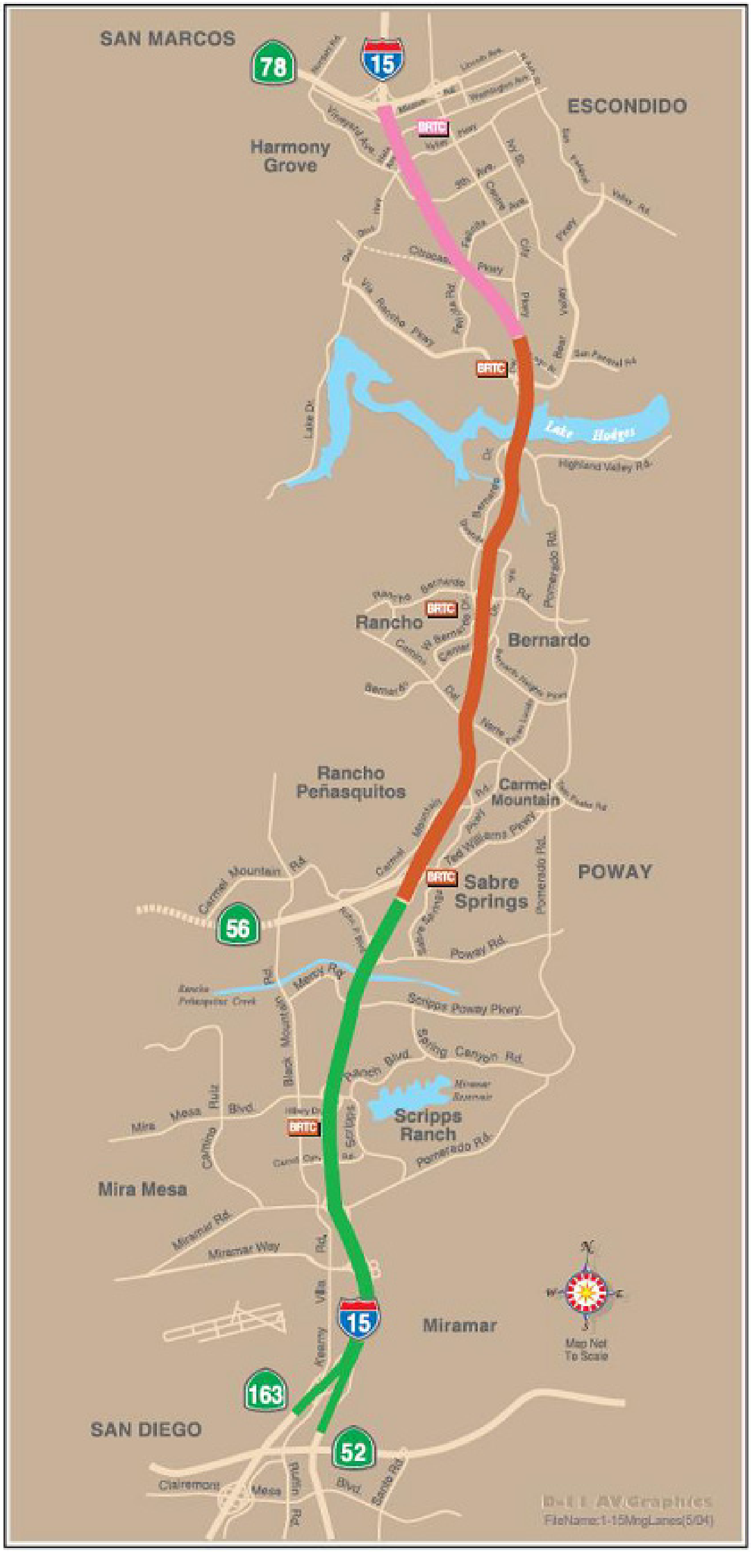
1.2.1 Overview of the San Diego ICM Deployment

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

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

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

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



San Diego Association of Governments, January 2011

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

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

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

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

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

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

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

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

Table 1-1. Summary of San Diego DSS Functionality

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

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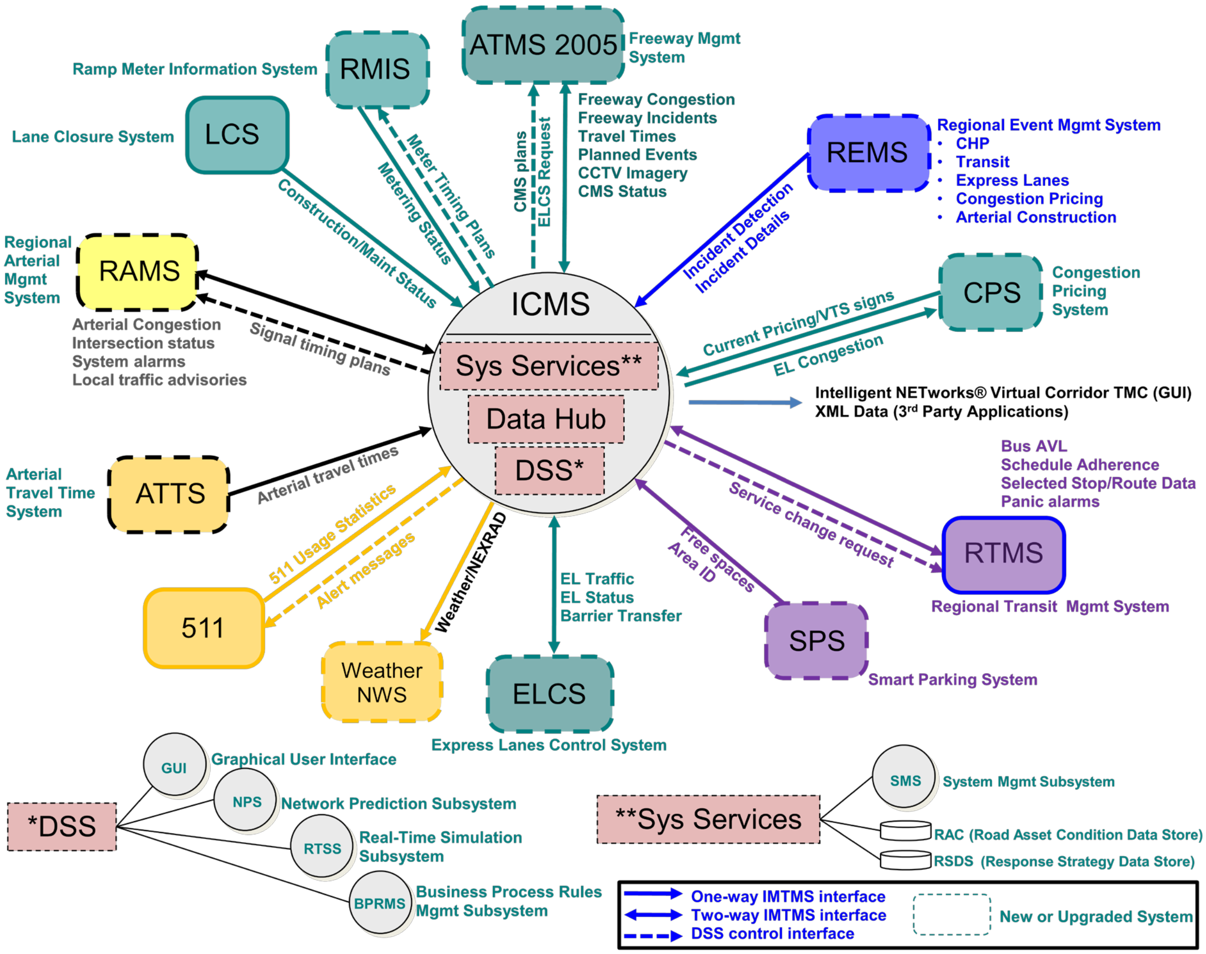

Figure 1-2. Context of San Diego ICM System Data Inputs and Outputs

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

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

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

1.2.1.1 Current Understanding of DSS Operations

Functionally, DSS will support the ability to automatically, semi-automatically, or manually generate suggested plans for modal actions in response to regional events. The significance and importance of the DSS lies in the fact that the response plans for short-term or long-term impacts on the corridor will be coordinated and not carried out in isolation as is usually the case. Generally DSS plans will be short-term plans, covering a range of up to several hours, or possibly days or weeks in the case of major disasters such as the recent October 2007 wildfires in San Diego County. The DSS relies on an Expert System that combines a rule base using incident response parameters with knowledge base information on roadway geometry and field device locations to automatically generate response plans.

Figure 1-3 provides a DSS-centric view of the Integrated Corridor Management System (ICMS). At a high-level, there are three key elements to the DSS functionality. The left side of the figure (the orange boxes and the ICMS data store) provides the off-line modeling capability and the response plans database. The right side of the figure (the green boxes) represents the current conditions gathered through the ICMS Data Hub and the interfacing systems. The middle of the figure (the red boxes) represents the online analysis of conditions and evaluation of response plans through a real-time simulation and predictive analysis. The learning and feedback connection reflects the offline analysis of the real-time simulation analysis using the Performance Measurement System (PeMS) data from the University of California-Berkeley, PATH and Caltrans that will inform for adjustments.

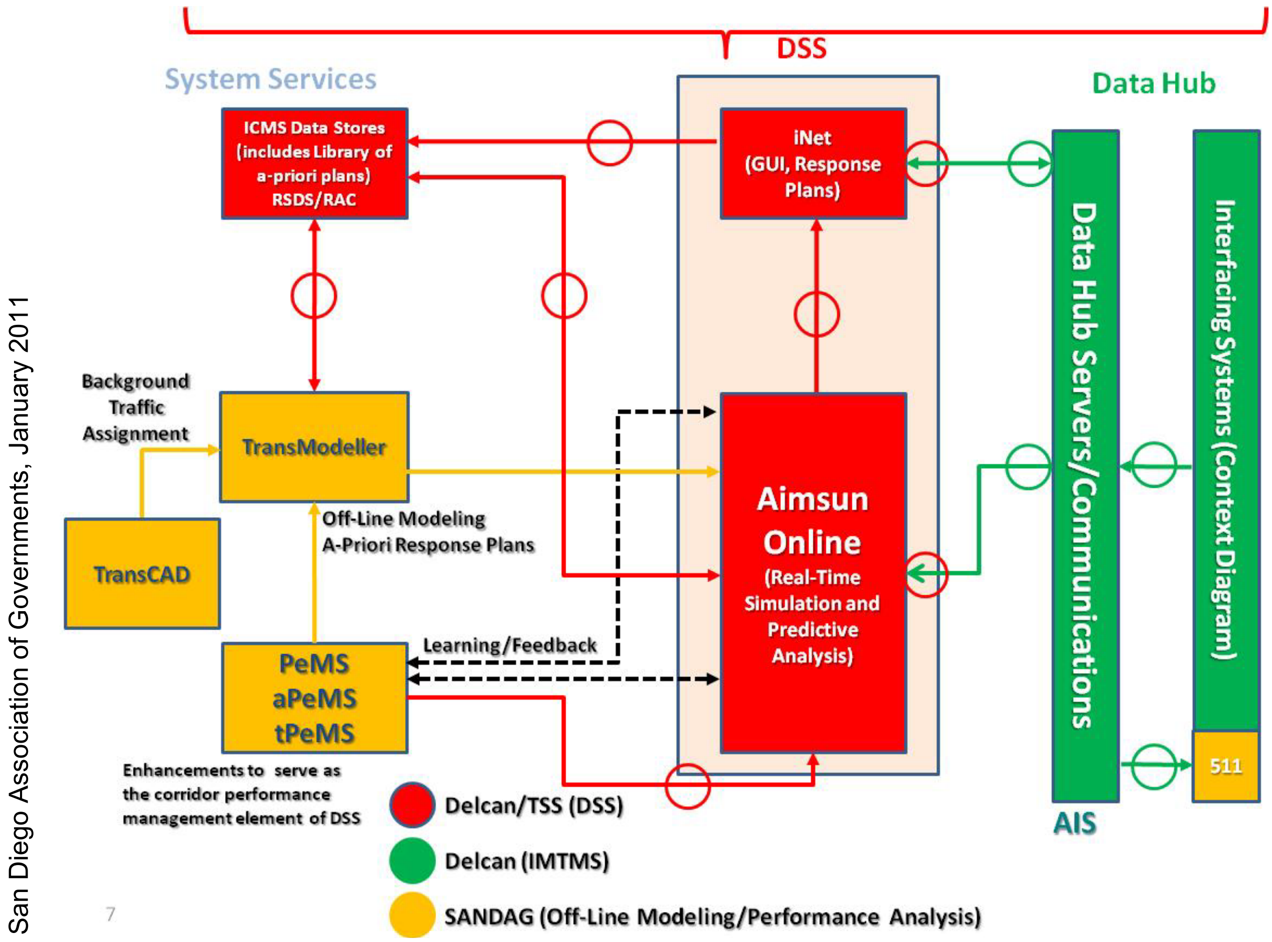

Figure 1-3. DSS-Centric View of the ICMS

Once an event is triggered (i.e., the congestion threshold has occurred or is imminent) in the system, the DSS evaluates various response plans for their suitability. Each response plan consists of pre-determined and staged action plans as shown in Figure 1-4. Once a response plan is selected, the various action plans go into effect at specific times in the response. It is important to note that "event" in the case of the DSS implies a congestion threshold that triggers the evaluation of response plans. The reason for the event can be any number of causes such as incidents, work zones, special events etc.

San Diego Association of Governments, January 2011

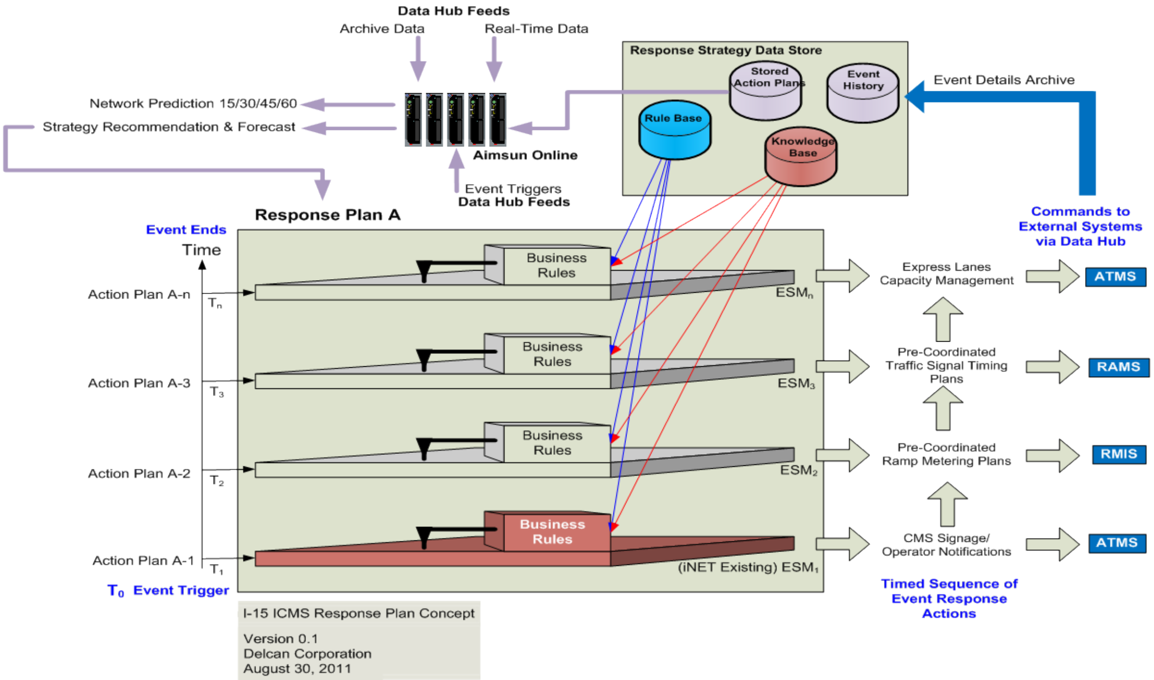

Figure 1-4. Response Plan Concept

Each response plan is also a function of the demand on the corridor and the event impact as shown in Table 1-2 and is defined by alignment of response postures across each mode based upon corridor conditions. A simple explanation of the table is that an aggressive response plan is required for a high-impact event during a high-demand condition whereas a low impact event on a low-demand situation might require only a conservative response plan. Currently, the site is working on developing the action plans, and the corresponding response plans for the corridor.

Table 1-2. Response Plan Alignments Across Demand and Event Impact

Response Posture		Event Impact (congestion, construction, incident, etc.)		
		Low	Medium	High
Demand on Corridor	Light	Conservative	Conservative	*(Event 2) Moderate*
	Moderate	Conservative	*Moderate*	**Aggressive**
	Heavy	*Moderate*	**Aggressive**	**(Event 1) Aggressive**

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1.2.2 San Diego ICM Deployment Schedule

Table 1-3 presents the San Diego ICM deployment schedule. As indicated in Table 1-3, individual components of the deployment will be completed in a phased manner, with full ICM system operations currently scheduled to commence in February 2013. The San Diego site team has indicated that they do expect, to at least some degree, to begin using individual components and associated ICM strategies as they become available prior to the overall system go-live. The approach to this analysis attempts to take that phasing into consideration. Since both the completion dates of the individual ICM components and the San Diego site team's utilization of them are expected to evolve as the ICM system design, implementation and shakedown periods progress, the approach presented in this test plan may flex somewhat in response.

Table 1-3. San Diego ICM Deployment Schedule

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

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1.2.3 Comparison to the Dallas ICM Deployment

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

- The San Diego corridor includes extensive bus rapid transit whereas the U.S. 75 corridor in Dallas includes the Red Line Light Rail Transit (LRT) service.
- The San Diego corridor includes concurrent flow HOT/managed lanes whereas the Dallas corridor includes HOV lanes:

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

1.3 National Evaluation Objectives and Process

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

1.3.1 U.S. DOT Hypotheses

The U.S. DOT has established the testing of eight "hypotheses" as the primary objective and analytical thrust of the ICM demonstration phase evaluation, as shown in Table 1-4. There are a number of cause-effect relationships among the U.S. DOT hypotheses; for example, enhanced response and control is dependent on enhanced situational awareness. These relationships will be examined through the evaluation in addition to testing the individual hypotheses. Another important relationship among the hypotheses is that DSS is actually a component of enhanced response and control and, depending on the specific role played by the DSS, may also contribute to improved situational awareness.

Table 1-4. U.S. DOT ICM Evaluation Hypotheses

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

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

1.3.2 Evaluation Analyses

The investigation of the eight U.S. DOT evaluation hypotheses have been organized into seven evaluation "analyses," shown in Table 1-5, which generally correlate with the hypotheses. A separate analysis investigates institutional and organizational issues, which relate to all of the hypotheses since the ability to achieve any intended ICM benefits depends upon successful institutional coordination and cooperation.

Table 1-5. Relationship Between U.S. DOT Hypotheses and Evaluation Analyses

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

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

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

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

1.3.3 Evaluation Process and Timeline

Figure 1-5 shows the anticipated sequence of evaluation activities. The evaluation will collect 12 months of baseline (pre-ICM deployment) data and, following a 6-month shakedown period, 12 months of post-deployment data.

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

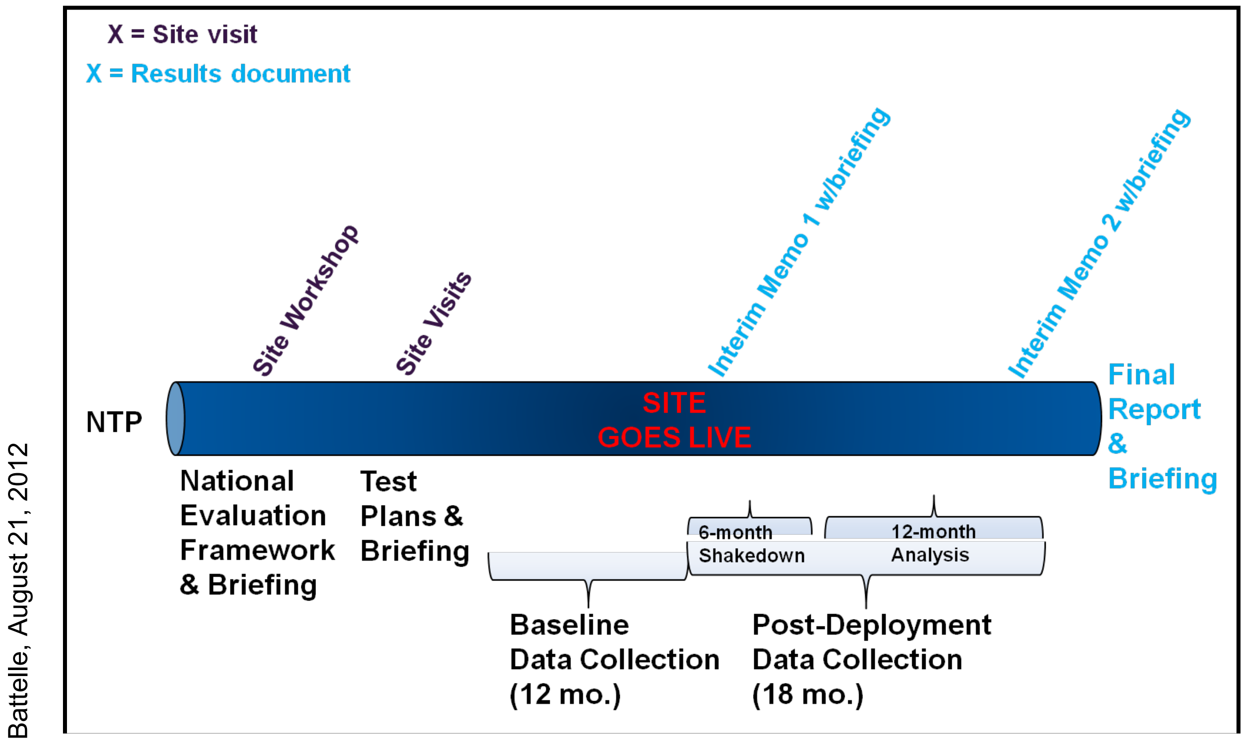

Figure 1-5. Sequence of Evaluation Activities

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

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

1.3.4 Roles and Responsibilities

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

2.0 ANALYSIS OVERVIEW

This chapter provides a high-level overview of the approach to the DSS Analysis, including a discussion of evaluation hypotheses to be tested and measures of effectiveness (MOEs). The DSS analysis is one of the two evaluation analyses that focus exclusively on "outputs"—the capabilities acquired by the transportation operating agencies as a result of ICM deployment. The other analysis focusing on outputs is the Technical Capability Analysis. The impact of the DSS on corridor performance outcomes is captured through the Corridor Performance Analysis.

Decision support systems can be considered the "brain" of ICM systems. They provide the critical information and decision making support necessary for transportation operating agencies to understand the significantly increased volume of incoming data and decide between an expanded (by virtue of the ICM deployment) and complex array of alternative actions (response plans)—a determination that can also provide predictions of the results of alternative response plans. This analysis will thoroughly explore specific performance characteristics of the DSS and the overall contributions of the DSS to ICM success. This will include:

- investigation of the ability of data fusion engine to effectively fuse[3] data and to be able to deal with non-converging data,
- the quality of responses generated by the DSS,
- the accuracy of DSS predictions of transportation system conditions 15 minutes or more into the future under steady state conditions,
- the speed of response plan generation, and
- how varying conditions and data loads (e.g., minor incidents, major incidents) impact DSS performance across these various dimensions of performance.

There is no quantitative "before" data since there is no formal DSS technology currently being used. As such, this analysis constitutes a case study and a lab test of capabilities rather than a before-after systems impact assessment.

Figure 2-1 graphically summarizes the approach to this analysis.

[3] Fusing data in San Diego's case implies utilizing individual streams of TMDD-compliant data from various corridor systems in the ICMS Data Hub to support the on-line evaluation of responses in the DSS through the simulation engine. The act of fusion does not necessarily imply combining data streams into a corridor-level mosaic. As such the success of data fusion is measured by having standardized data across the entire corridor that can be fed into the DSS engine.

Battelle, August 21, 2012

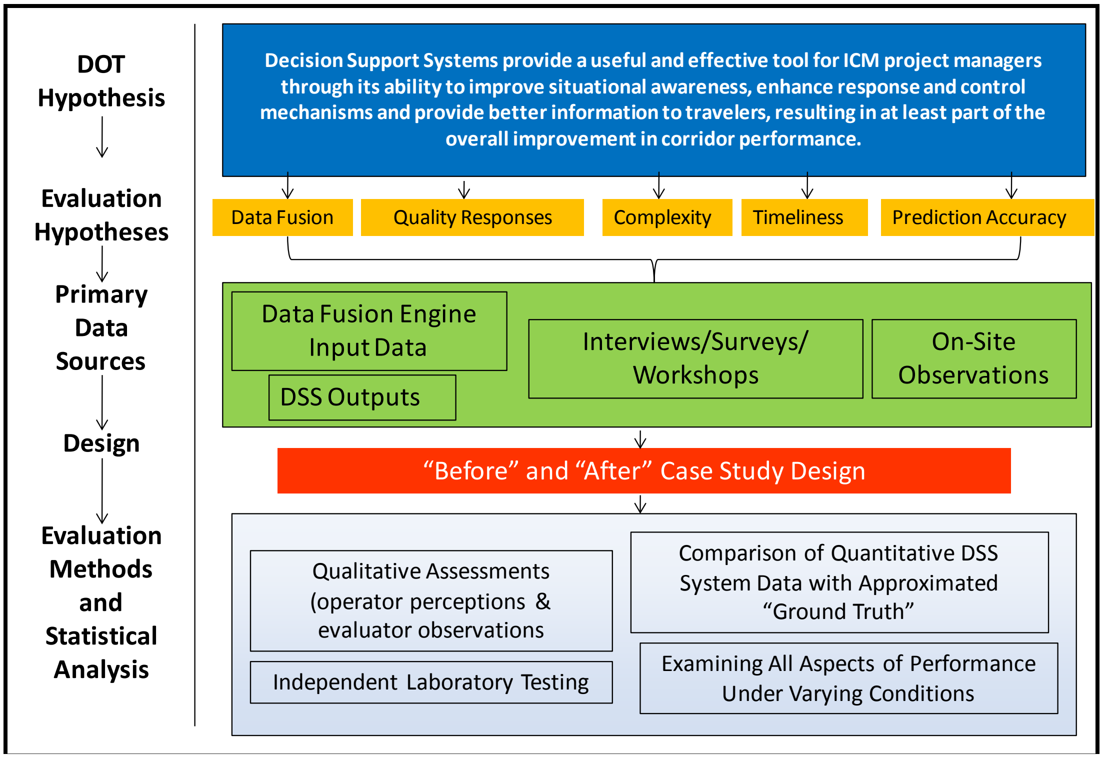

Figure 2-1. Overview of Decision Support Systems Analysis

Table 2-1 provides the analysis' primary data elements, which are described for evaluating associated MOEs. The national evaluation team will analyze each of the data elements independently, linking the results to the aforementioned evaluation hypotheses which are also listed in the table.

The data elements are categorized by quantitative and qualitative data. A majority of the quantitative data elements will be obtainable through the acquisition of system data from the DSS' fusion engine, while the qualitative data elements will be obtained from manually distributed surveys that will track user impressions.

Discussions of quantitative and qualitative data elements are presented in Chapters 3 and 4, respectively.

Table 2-1. Decision Support System Analysis Hypotheses, MOEs, Data, and Sources

Evaluation Type	Data Element(s)	MOE	Related Hypotheses
Quantitative Data			
1. Data Fusion Capability Data[4]	1.1 San Diego ICMS Data Hub Inputs 1.2 San Diego ICMS Data Hub Outputs 1.3 University of Maryland (UMD) Analysis: Outputs	• Success rate of ICMS in taking data from disparate sources and standardizing data • Success rate of ICMS in recognizing overlaps in data, if any • Success rate of ICMS in recognizing and fixing gaps in data or missing data streams	DSS can take data from disparate sources, standardize/clean it, and turn it into an interpretable and mutually comparable format, successfully recognizing overlaps, gaps, or other data stream anomalies and account for it appropriately as described in the design specifications.
2. DSS Outcome Prediction Data	2.1 UMD Analysis: generated DSS Simulated Output	• Difference between predicted outcomes and actual operation conditions in terms of corridor performance (volumes, speeds, travel times, throughput), in various scenarios	DSS accurately describes the effect of the various responses
3. DSS Outcomes Data	3.1 UMD Analysis: Outcomes	• Percentage of times operator implements recommended responses • Percentage of times operator alters recommended responses	DSS suggests multiple reasonable strategies and provides the human decision makers with the relevant information to choose between them
4. DSS Timeliness Data	4.1 UMD Analysis: Generated DSS Response Plans	• Average time DSS takes to deliver an actionable response plan[5] • Average time for DSS to deliver predictions of strategy outcomes[5]	DSS provides recommended strategies with simulated results quickly and any steps that require human intervention can be completed expediently and easily
		• Average number of response plans generated per event-hour[6]	Fewer response plans will be recommended by the DSS during short events during which conditions are relatively stable versus longer events during which conditions vary considerably

[4] See the previous footnote about San Diego's data fusion.

[5] These MOEs will be tracked against the requirements established by San Diego as part of their system requirements documents.

[6] The national evaluation team believes that this data will be available in the ICMS system data stream provided by the San Diego site team but was not able to fully verify this.

Table 2-1. Decision Support System Analysis Hypotheses, MOEs, Data, and Sources (Continued)

Evaluation Type	Data Element(s)	MOE	Related Hypotheses
Qualitative Data			
5. Operator Perceptions	5.1 TMC Operator Survey[7]	• Responses consistent with operators' experience and perceptions • Perceived quality of responses, including improvement relative to any comparable pre-ICM approaches • Perceived usefulness of information provided to operators for interpretation and decision making, including improvements relative to pre-ICM approaches • Level of operator intervention in altering recommended responses[8]	DSS suggests multiple reasonable strategies and provides the human decision makers with the relevant information to choose between them
		• Perceived accuracy of DSS predictions	DSS provides recommended strategies with simulated results quickly and any steps that require human intervention can be completed expediently and easily
6. ICM Project Development Team (PDT) Perceptions	6.1 ICM PDT Committee Member Survey	• Perceived quality of responses, including improvement relative to any comparable pre-ICM approaches	DSS suggests multiple reasonable strategies and provides the human decision makers with the relevant information to choose between them
		• Perceived accuracy of DSS predictions	DSS provides recommended strategies with simulated results quickly and any steps that require human intervention can be completed expediently and easily

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[7] For the purpose of this test plan, the term "operator" refers to not only the TMC operators, but the various corridor agency operators who are responding to the DSS generated response plans.

[8] This MOE applies only to those responses which require operator intervention (such as posting DMS signs). The test plan recognizes that the DSS may recommend responses which may not require operator intervention and will be implemented automatically based on previously agreed upon decisions.

3.0 QUANTITATIVE DATA

This chapter identifies the quantitative data elements to be used in the Decision Support System analysis. Table 3-1 summarizes the data requirements for the Decision Support System Analysis Test Plan. The details associated with the source, timing, and other details are discussed in the sections that follow.

Due to the fact that the underlying databases are still under development, the national evaluation team has not yet been given the opportunity to view the actual ICMS Data Hub data feeds. Therefore, much of this test plan is based on a high-level understanding of the ICMS from the San Diego ICM System Requirements and Concept of Operation.

3.1 ICMS Data Hub Data

It is assumed that ICMS Data Hub will include all data from connected systems including speeds, volumes, incident characteristics (such as location, type, lane status, and responders), Dynamic Message Sign (DMS) messages, signal data, weather, etc. It is also assumed that ICMS will include detailed time-stamps for data entering and leaving the system. The ICMS Data Hub will also contain the number of times the DSS generated response plans based on triggers established in the system.

3.2 DSS Outcome Prediction Data

Predicted outcome data includes speed, volume, queue length, clearance time, return to normal time, or other "expected future" data about the traffic network. The national evaluation team will examine this prediction data to see if it is accurate in terms of the expected values, trends, or accurate in terms of the amount of time it takes for the road to reach the predicted values. As with all other data elements, it is expected that this data will include timestamps for the time/date at which the prediction was made along with timestamps for when the predictions are expected to become a reality. Prediction data will be compared with DSS outcomes data described in Section 3.3.

3.3 DSS Outcomes Data

DSS outcomes data is the actual values that are measured and recorded after a particular DSS plan is implemented. As with the "prediction data" listed in Section 3.2, outcomes data includes speed, volume, queue length, clearance time, return to normal time, etc. but it is the actual values that are recorded instead of just the prediction of what the values will be.

Table 3-1. Quantitative Data Summary

Data Element	Location	Data Source	Data Collection Frequency	Data Collection Period (post-)		Data Collection Responsible Party	Data Transmittal
				Start	End		
Data Fusion Capability Data							
1.1 San Diego ICMS Data Hub Inputs	Entire ICM Corridor (see Figure 1-1)	ICMS	Continuous	Feb 2013	July 2014	ICMS Data Hub	Continuous (University of Maryland [UMD] Data Feed)
1.2 San Diego ICMS Data Hub Outputs	Entire ICM Corridor (see Figure 1-1)	ICMS	Continuous	Feb 2013	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
1.3 UMD Analysis: Outputs	Entire ICM Corridor (see Figure 1-1)	ICMS	Continuous	Feb 2013	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
DSS Outcome Prediction Data							
2.1 UMD Analysis: Generated DSS Output Comparisons with Observed Conditions	Entire ICM Corridor (see Figure 1-1)	UMD	Continuous	Feb 2013	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
DSS Outcomes Data							
3.1 UMD Analysis: Outcomes	Entire ICM Corridor (see Figure 1-1)	ICMS	Continuous	Feb 2013	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)
DSS Timeliness Data							
4.1 UMD Analysis: Generated DSS Response Plans	Entire ICM Corridor (see Figure 1-1)	UMD	Continuous	Feb 2013	July 2014	ICMS Data Hub	Continuous (UMD Data Feed)

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3.4 DSS Timeliness Data

To evaluate "timeliness," it is imperative that timestamps from input data are collected along with timestamps for DSS output. For example, it will be important to know that speeds decreased on a roadway at 7:50:02 AM on Dec. 21st, 2011, then an incident was detected and entered into the system at 7:55:03 AM, and then to know that the DSS suggested response plan was generated and "delivered" to the operator at 7:58:05 AM. Understanding the time lags, where they occur, whether they are significant in any way, and how the timeliness may or may not change depending on the complexity of the scenario or current stress on the system will be extremely important. If complex scenarios do not naturally present themselves during the DSS operational phase, then it may be necessary to introduce "pressure testing" in some form. It is, however, quite unlikely that large, complex incidents will not occur throughout the evaluation phase. In this context, "pressure testing" means that if large, complex incidents do not occur naturally during the evaluation period, the University of Maryland (UMD) will develop simulated DSS input data representing such conditions.

Another aspect of the evaluation of DSS timeliness will document and consider the frequency at which the DSS generates response plan recommendations during specific incidents/events and—subjectively—consider whether that frequency appears appropriate given the duration of the incident/event and the variability in conditions over the course of the incident/event. This investigation is based on the premise (supported to some extent through research on ramp metering algorithms in California) that it may be possible to identify/recommend interventions prematurely, that is, to diagnose and recommend a response before traffic and travelers have been able to adjust to the previous intervention. In such a case, the DSS would be recommending responses based on analysis of a traffic/transportation pattern that was unstable—still in flux from the previous response action or intervention. At a minimum, this analysis will document (for a representative sample of incidents/events) the frequency of response plan recommendations by the DSS. This analysis will also endeavor, to the extent possible, to draw observations relative to the appropriateness of the observed frequencies. For example, one response plan implementation over a dynamic, evolving 3-hour incident would appear—on the face of it—possibly too infrequent; that is, not reactive enough to changing conditions over the course of the incident/event. Likewise, generation of a series of 10 DSS-recommended response plans over a fairly static, 28-minute incident may appear too frequent. It is not expected that this analysis will fully address these issues but rather it is intended to take advantage of the available data to advance the currently very limited understanding of these considerations.

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4.0 QUALITATIVE DATA

This chapter identifies the qualitative data elements to be used in the Decision Support System Analysis. Table 4-1 summarizes key attributes of each data collection activity and the sections that follow provide additional detail for each activity, including survey questionnaires.

Table 4-1. Qualitative Data Summary

Data Collection Activity	Data Collection Periods		Data Collection Schedule		Data Collection Responsible Party	Data Transmittal
	Baseline	Post-Deployment	Baseline	Post Deployment		
5.1 TMC Operator Survey[9]		X	N/A	Sept 15, 2013 Jan 13, 2014 Apr 15, 2014 Jul 15, 2014 + 6 Pulse Surveys	National Evaluation Team via the San Diego Site Team Lead	Completed Surveys sent to National Evaluation Team
6.1 ICM PDT Committee Member Survey		X	N/A	Sept 15, 2013 Jan 13, 2014 Apr 15, 2014 Jul 15, 2014 + 6 Pulse Surveys	National Evaluation Team via the San Diego Site Team Lead	Completed Surveys sent to National Evaluation Team

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4.1 TMC Operator Survey

4.1.1 Purpose

The purpose behind surveying the transit, local agency and TMC operators is to garner impressions of DSS operating results from a qualitative approach before and after implementation of the DSS. Operators will be working closely with the San Diego site team lead, but are also the front line in any traffic incident management plan, having the final word in executing the DSS recommended automated response based on the information available to them at the time. For this reason, they can provide informed impressions about DSS.

[9] 2 Operator survey questions from 5.1 (*Were the DSS recommended responses concerning the development of DMS messages, signal timing changes, ramp metering changes, etc consistent with your experience and expectations as an operator?* and – *Please rate how your agreement with the following: "The information provided to me by the DSS was useful in deciding what response plan I ultimately implemented"*) will be asked during the 'shakedown' period as well, in addition to the post deployment period specified in this table.

4.1.2 Approach

This survey will be administered to the transit, local agency and TMC operators located within and adjacent to the corridor, shown in Table 4-2. The national evaluation team[10] will provide electronic survey questionnaires to the San Diego survey participants who will be directly responsible for their completion.

Table 4-2. Tentative List of TMC Operator Survey Participants

Involved Parties	Agency	Tentative Survey Participant
Transit Operators	MTS	Devin Braun
		Mike Daney
	Veolia (contractor)	TBD
TMC Operators	Caltrans	Lima Kopitch
		Paul English
		Valerie Pekarek
		Mike Egan
Local Agency Operators	City of Poway	Zoubir Ouadah
	City of San Diego	Duncan Hughes
		Eddie Flores
	City of Escondido	Ali Shahzad
		Chris Landis

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The survey will be distributed both quarterly and following specific events. The quarterly survey to the operators will occur on the following dates[9]:

- September 15, 2013
- January 15, 2014
- April 15, 2014
- July 15, 2014

The same survey will be distributed within 1 week following severity-specific events that will serve as case studies. These surveys will summarize the operators' perceptions of a specific event, within a timeframe that allows for the event to be easily recalled. These "pulse" surveys will be given twice for events classified in each of the TMC graded event severity categories (minor, intermediate, and severe) during the post-DSS deployment timeframe. The determination of which incidents or events will be the subject of the pulse surveys will be made by the Volpe Center, who will administer the traveler pulse surveys. The national evaluation team's understanding is that the Volpe Center will alert the Battelle evaluation team when they are planning to administer a traveler pulse survey so that the Battelle evaluation team can administer their DSS and Technical Capability Analysis pulse surveys.

[10] Email addresses for all participants should be provided by the site team lead. The national evaluation team lead will coordinate with the site team lead as to when the surveys will be emailed out in order to facilitate any local notification and concurrence from personnel.

The San Diego site team lead will have the responsibility of notifying the national evaluation team analysis lead for the Technical Capability Analysis within 72 hours of the sample event's execution. This timeframe will allow the Analysis Lead to distribute the survey through electronic (email) means to the various agency operators.

These event-driven surveys will be administered in conjunction with the "pulse" surveys for the Corridor Performance (Mobility) and Traveler Response analyses (described in separate test plans), thereby minimizing the distribution of too many surveys over the course of the evaluation. The results from these "pulse" surveys, and the fixed-date quarterly surveys, will allow other test plan analyses leaders to clarify their results through the sharing of mutually applicable survey data.

4.1.3 Questionnaire

Table 4-3 contains the proposed survey questions and their associated response categories.

Table 4-3. Questions in the TMC Operator Survey

Question (Numbers reference data elements from Table 2-1)	Response Options
5.1a Were the DSS recommended responses (for example, the development of DMS messages, signal timing changes, ramp metering changes, or any other ICM-strategy-implementing actions with which you are familiar or for which you are responsible) consistent with your experience and expectations as an operator?[9]	(1) Very consistent
	(2) Somewhat consistent
	(3) Neither consistent nor inconsistent
	(4) Somewhat inconsistent
	(5) Very inconsistent
5.1b How would you rate the quality of incident responses (for example, the development of DMS messages, signal timing changes, ramp metering changes, or any other recommended actions with which you are familiar or for which you are responsible) given the resources and information you have available to yourself as an operator?	(1) Very accurate
	(2) Somewhat accurate
	(3) Neither accurate nor inaccurate
	(4) Somewhat inaccurate
	(5) Very inaccurate
5.1c Please rate how you agree with the following: "The information provided to me by the DSS was useful in deciding what response plan I ultimately implemented."[9]	(1) Strongly agree
	(2) Somewhat agree
	(3) Neither agree nor disagree
	(4) Somewhat disagree
	(5) Strongly disagree
5.1d Prior to DSS, how would you rate the quality of incident responses given the resources and information available to yourself as an operator?[11]	(1) Very good
	(2) Good
	(3) Fair
	(4) Not very good
	(5) Very bad

[11] The Evaluation Team will also consult the AMS Stage 2 results for comparative data.

Table 4-3. Questions in the TMC Operator Survey (Continued)

Question (Numbers reference data elements from Table 2-1)	Response Options
5.1e Please rate the accuracy of the DSS predictions of travel conditions.	(1) Very accurate
	(2) Somewhat accurate
	(3) Neither accurate nor inaccurate
	(4) Somewhat inaccurate
	(5) Very inaccurate
5.1f Rate your perceived usefulness of the DSS predictions.	(1) Very useful
	(2) Somewhat useful
	(3) Seldom useful
	(4) Rarely useful
	(5) Never useful

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4.2 ICM Project Development Team (PDT) Committee Member Survey

4.2.1 Purpose

The PDT committee is tasked with overseeing the successful deployment of the ICMS relative to its functional capabilities. The committee, listed in Table 4-4, meets on a quarterly basis to review how traffic congestion has been mitigated through the deployment of ICM resources, most relevant to this analysis, the execution of DSS response plans. The committee, as described to the national evaluation team, is tasked with reviewing a sampling of incidents and determining what level of success the control room experienced in utilizing DSS-recommended response plans.

The purpose of surveying this committee is to gauge the impressions of its members based on its assessment of the DSS functionality. The committee, comprised of several stakeholder agencies, will provide a macro (high level) perspective on the performance of the DSS.

Table 4-4. PDT Operations Committee Members

Agency	PDT Operations Committee Member
MTS	Devin Braun
Caltrans	Lima Kopitch
City of Poway	Zoubir Ouadah
City of San Diego	Duncan Hughes
City of Escondido	Ali Shahzad
Caltrans D11	Tim Bouquin
	Everett Townsend
	Cindee Feaver
	Lawrence Emerson
	Shahin Sepassi
SANDAG	Ingrid Weisenbach

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4.2.2 Approach

Each member of the committee will be surveyed four times during the last ten months of the post-deployment period, September 2013 through July 2014. The committee is responsible for assessing the impact and success in ICM deployment. Much of the initial assessment will occur over the first few months into the post-deployment period. As such, it will be appropriate and most beneficial to survey its members after the first couple months of the post-deployment period. Surveys will be conducted on the following dates:

- September 15, 2013
- January 15, 2013
- April 15, 2014
- July 15, 2014

4.2.3 Questionnaire

The survey will be presented in an electronic (email) format to each of the PDT committee participants, with the results being tabulated by the national evaluation team. The survey will include the following questions and multiple choice answers that will make it easier to record results in an objective manner. Each response is weighted, allowing the final results to be tabulated and reflective of a specific defined value. This survey will be administered only during the DSS deployment phase.

Table 4-5. Questions in the ICM PDT Committee Member Survey

Question (Numbers reference data elements from Table 2-1)	Response Options
6.1a Please rate the accuracy of the DSS predictions of travel conditions.	(1) Very accurate
	(2) Somewhat accurate
	(3) Neither accurate nor inaccurate
	(4) Somewhat inaccurate
	(5) Very inaccurate
6.1b Please rate the perceived accuracy and effectiveness of the DSS recommended corridor-wide responses being generated and executed.	(1) Very accurate
	(2) Somewhat accurate
	(3) Neither accurate nor inaccurate
	(4) Somewhat inaccurate
	(5) Very inaccurate

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5.0 DATA ANALYSIS

This section presents the approach to evaluating the hypotheses depicted in Figure 2-1. Detailed test plans have been developed for each of the four hypotheses that analyze their associated measures of effectiveness and the reporting of the findings in the technical memos described in Section 1.3.3.

To systematically analyze and interpret the effect of various roadway conditions on the DSS capabilities, special attention will be given to normal daily conditions and periods influenced by special scenarios such as:

- Severe weather (including incidents involving forest fires)
- Major traffic incidents
- Major construction/maintenance
- Holidays (both local and national)
- Incidents involving the Department of Homeland Security (including military)
- Major events (e.g., concerts, community festivities, air shows)

The national evaluation team will track weather alerts issued by the National Weather Service (NWS). It is likely that the Weather alert information from the NWS will also be stored in ICMS. In addition to proactively observing and tracking weather events, the national evaluation team will review the data that will be obtained from the ICMS portal on a monthly basis to confirm all severe weather events are recorded. Once a weather event is identified as potentially impacting DSS results, the national evaluation team will gather the following information from the National Weather Service for evaluation: type of event (i.e., thunderstorms, high winds), date and time of the event, duration, event details (e.g., amount of precipitation), and areas of impact.

Planned special events may include but are not limited to sporting events and concerts. Data needed for those events are date, time, duration and location of each event, areas and routes impacted, and traffic management plan implemented. The national evaluation team will obtain planned special event data via the ICMS portal monthly.

The DSS responses to all of the scenarios represented in this test plan will be compared based on not only normal operating conditions, but also those listed above, thereby evaluating the DSS under different levels of transportation system complexity.

5.1 Data Fusion Capability Data

The national evaluation team will conduct an in-depth assessment of the effectiveness and appropriateness of the San Diego site‘s capability for and approach to data fusion. It is important to note that San Diego’s approach to data fusion does not imply that multiple data sources covering the exact same geographic area are being merged and compared against one another, but rather that multiple data streams are being standardized (TMDD v3.0) and/or otherwise provided to a central simulation engine as part of the DSS.

Individual data streams from the site's Data Hub will be fed into the UMD Regional Integrated Transportation Information System for storage and later analysis. The analysis will identify if and whether data is ignored and/or dropped based on quality metrics, data imputation methodologies, how time-of-day or system complexity may factor, and other data quality checks per system design specifications as it gets used in the DSS.

In order to substantiate the objectives associated with hypotheses in this area, the following MOE will be analyzed post-DSS deployment. The MOE will be evaluated solely from a quantitative approach:

- The success rate of the data fusion engine in recognizing and fixing gaps in the data.

Special attention will be given to "data gaps" and how the fusion engine handles these occurrences. For example, if one or more of these data streams is unavailable, how does the system respond? Does it cease to provide recommendations, does it rely on historical data, impute data, or something else? If imputation algorithms are used, have they been implemented correctly? The input data will be compared to the output data and compared against several different known imputation algorithms for comparison.

The results may be presented graphically in charts, comparing the time of day performance, performance during various conditions (high traffic, low traffic, and multiple simultaneous incidents), along with an in-depth explanation and analysis of what factors may or may not be affecting the fusion engine's capabilities and outputs.

5.2 DSS Accuracy

The analysis of whether the DSS is producing actionable response plans and appropriate forecasts of mobility conditions in a timely manner will be crucial in determining whether it is performing as designed, with appropriate timing between forecasts and suggested plans. To measure this, two methods will be instituted. First, a quantifiable analysis of the predicted outcomes produced by the DSS will be compared to the actual conditions. Variances will be tracked and presented in graph-based comparative analysis. San Diego plans to conduct a similar assessment quarterly comparing predicted information with observed PeMS data.

Second, the national evaluation team will survey the PDT committee for their impressions relative to the predictive accuracy of DSS outputs. The committee will maintain a broad-based observance of the DSS outputs over the post-deployment period (August 2013 – July 2014) and, therefore, will be well qualified to assess the success of the system. They will be polled via a survey quarterly, starting in the second quarter of the post-deployment period. Each survey will cover their impressions over the previous 90 days.

In order to substantiate the objectives associated with this hypothesis, the MOEs will be analyzed post-DSS deployment. The following MOE's will be evaluated from a quantitative approach:

- The difference between predicted outcomes and the actual operation conditions in terms of corridor performance (volumes, speeds, travel times, throughput) – in various scenarios

The following MOE's will be evaluated from a qualitative approach:

- Perceived accuracy of DSS generated predictions (per the PDT Committee)
- Perceived accuracy of DSS generated predictions (per the transit, local agency and TMC operators)
- Average number of response plans generated per event-hour

5.3 Timeliness

Obtaining forecasted conditions and incident response plans in a timely manner will be a key issue for the TMC operators and partner agencies. Therefore, the national evaluation team will track the times it takes to deliver response plans and strategy outcomes. As noted in Section 3.4, this analysis will also document—for a representative sample of incidents/events of varying durations and complexity—the frequency at which the DSS generates recommended response plans over the duration of an incident/event and, if possible, offer some observations relative to the apparent appropriateness of that frequency.

As data is received by the national evaluation team, abnormal spikes or dips in activity levels (outliers) will be segregated and further analyzed for the contributing factor(s), as listed below. Once the causal factor(s) has been identified, the data will be classified and separated from the now 'normalized data' (normal operations data) and compared relative to other events in its same category (e.g., major traffic accident, July 4th holiday, major planned events such as football games), during post-ICM deployment. This baseline comparison analysis will allow the national evaluation team to compare system performance during various types of operational conditions to see if the system is more or less efficient in certain types of scenarios.

In order to substantiate the objectives associated with hypotheses in this area, the following MOEs will be analyzed post-DSS deployment. Each MOE will be evaluated solely from a quantitative approach and compared to the specification established in the systems requirement documents:

- Average time for the DSS to deliver actionable response plan,
- Average time for the DSS to deliver predictions of strategy outcomes.

The results will be presented graphically in charts, comparing the time of day performance, complexity performance, etc.

Another aspect of the evaluation of DSS timeliness will document and consider the frequency at which the DSS generates response plan recommendations during specific incidents/events and—subjectively—consider whether that frequency appears appropriate given the duration of the incident/event and the variability in conditions over the course of the incident/event. This investigation is based on the premise (supported to some extent through research on ramp metering algorithms in California) that it may be possible to identify/recommend interventions prematurely, that is, to diagnose and recommend a response before traffic and travelers have been able to adjust to the previous intervention. In such a case, the DSS would be recommending responses based on analysis of a traffic/transportation pattern that was unstable—

still in flux from the previous response action or intervention. At a minimum, this analysis will document (for a representative sample of incidents/events) the frequency of response plan recommendations by the DSS. This analysis will also endeavor, to the extent possible, to draw observations relative to the appropriateness of the observed frequencies. For example, one response plan implementation over a dynamic, evolving 3-hour incident would appear—on the face of it—possibly too infrequent; that is, not reactive enough to changing conditions over the course of the incident/event. Likewise, generation of a series of 10 DSS-recommended response plans over a fairly static, 28-minute incident may appear too frequent. It is not expected that this analysis will fully address these issues but rather it is intended to take advantage of the available data to advance the currently very limited understanding of these considerations.

5.4 Quality of the DSS Response

The level of intervention, percentage of interventions, and acceptance rates of the originally recommended DSS response plans, will be measured over the duration of the post-deployment period, reflecting trends during normal operating conditions and unique conditions (i.e., major accidents, heavy volume travel days, special events, etc.).

The goal of the DSS is to intelligently gather agency data and compile potential action plans (responses) that the TMC operator can administer with limited intervention. A high level of intervention would equate to poor output quality.

In order to substantiate the objectives associated with this hypothesis, the MOEs will be analyzed post-DSS deployment. The following MOE's will be evaluated from a quantitative approach:

- Percentage of times operator implements recommended responses from DSS,
- Percentage of times operator alters recommended responses (without dismissing it completely), and

The following MOE's will be evaluated from a qualitative approach:

- Responses consistent with the operator's experience and perceptions (per the operators),
- Perceived quality of responses, including improvements relative to any comparable pre-ICM approaches (per the operators),
- Perceived quality of responses, including improvements relative to any comparable pre-ICM approaches (per the PDT Committee),
- Perceived usefulness of information provided to operators for interpretation and decision making, including improvements relative to pre-ICM approaches (per the operators),
- Level of operator intervention in altering recommended responses (per the TMC operators).

It is understood that an operation's standard operating procedures or 'culture' may take time to transition from a manual response process to a more 'verify the DSS response plan and execute' mode of operation. Therefore, resulting technical memos and the final analysis will include a narrative describing the level of normal operator intervention taking place with respect to the implementation of the DSS response plans over the course of the surveys.

5.5 Exogenous Factors

The following exogenous factors could have an impact on not only data collection, but the ability of the national evaluation team to analyze the data in relationship to the MOEs and associated hypotheses.

- Unrelated and related software (new software being introduced to the existing ATMS infrastructure or updated to the DSS itself)/system upgrades over the course of the analysis could have an impact on data availability. Prior to each data collection point, monthly for most of the quantitative data and quarterly for most of the qualitative data, the national evaluation team will inquire as to the possibility of any data shifts based on technical upgrades or modifications to the software being used.

  Should these data altering circumstances present themselves, a tailored approach to screening and normalization of affected data will be developed before the data are used in the analysis or such data will need to be excluded from the analysis if data normalization cannot resolve the data quality issue.

- Operator tenure relative to their comfort levels when it comes to modifying DSS-generated response plans could have an impact on the MOEs associated with the percentage of times an operator alters a recommended response or the level an operator alters the recommended response. In response to this, the national evaluation team will assess the tenure of the operator staff quarterly and determine whether this factor could potentially affect the resulting statistics and whether there are any grounds for normalizing the data.

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6.0 RISKS AND MITIGATIONS

Table 6-1 identifies the risks associated with this analysis and the national evaluation team's response plan for each risk.

Table 6-1. Risks and Mitigations

Risk	Mitigation Strategy
1. Availability of both raw and processed data in a form easily accessible to the national evaluation team.	This is a proverbial "show stopper" for this analysis, therefore, the national evaluation team will work closely with San Diego site team to determine appropriate connection points for real-time feeds going into the Data Hub (ICMS) along with feeds coming out of ICMS.
2. Time-stamping of system data	Also a "show stopper," should time stamping of the data not be possible, accurate, or synchronized across platforms. Potentially reducing the continuous collection of data to pre-planned data "packs" that can be recorded on an as-received basis may be one undesirable alternative.
3. Additional detail on planned DSS functionality and tracking through the design and implementation process.	Without at least minimal access to the DSS interface, full understanding of functionality, usability, and operator interaction will be nearly impossible. Until the actual DSS is operational, there will be questions relative to its actual reporting capability. Should not all of the desired functionality (assumed in this test plan) be realized, the national evaluation team will work with the DSS site team to determine alternative method for data collection in the form of manual strike sheets and data recording processes.

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ITS Joint Program Office-HOIT
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Washington, DC 20590

Toll-Free "Help Line" 866-367-7487
www.its.dot.gov

Publication Number FHWA-JPO-13-050

U.S. Department of Transportation