Integrated Corridor Management Initiative: Demonstration Phase Evaluation

Final National Evaluation Framework

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16. Abstract

This report provides an analytical framework for evaluating the two field deployments under the United States Department of Transportation (U.S. DOT) Integrated Corridor Management (ICM) Initiative Demonstration Phase. The San Diego Interstate 15 corridor deployers and the Dallas U.S. 75 corridor deployers are implementing a suite of strategies aimed at balancing corridor transportation supply and demand to promote overall corridor efficiency and safety. The strategies include decision support systems to aid transportation operators in synthesizing incoming transportation system data and to develop, select and modify response plans; center-to-center information sharing and distribution strategies to promote coordinated, multi-modal and multi-agency responses; traffic signal timing adjustments and short-term transit capacity additions; and enhanced pre-trip and en-route traveler information to shift travelers to alternative modes or routes or to postpone trips to less congested periods. The evaluation will investigate and document the investments made by both sites, including ICM-related changes in policies and procedures; document and evaluate the capabilities acquired through ICM deployment and how those capabilities were utilized; and assess the impacts of the deployments, including mobility, safety, air quality and overall benefit-cost. Institutional and organization issues and lessons learned will also be investigated. The evaluation features eight individual analyses focusing on specific ICM capabilities and types of impacts.

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LIST OF ABBREVIATIONS

AMS	Analysis, Modeling and Simulation
AQ	Air quality
ATIS	Advanced traveler information system
ATMS	Active Traffic Management System
AVL	Automatic vehicle location
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio
Caltrans	California Department of Transportation
COTM	Contracting Officer Technical Manager
CCTV	Closed-circuit television
CHP	California Highway Patrol
DART	Dallas Area Rapid Transit
DHS	Department of Homeland Security
DMS	Dynamic message signs
DOT	Department of Transportation
DSS	Decision support systems
EB	Empirical Bayes
EMS	Emergency medical services
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GLM	General linear models
GUI	Graphical User Interface
HOT	High-occupancy tolling
HOV	High-occupancy vehicle
HTTP	Hypertext Transfer Protocol
ICM	Integrated Corridor Management
IMTMS	Intermodal Transportation Management System
I-635	Lyndon B. Johnson Freeway
I&O	Institutional and Organizational
ISP	Information service provider

ITS	Intelligent transportation systems
ITS CEO	Intelligent Transportation Systems Chief Executive Officer
KTT	Knowledge and Technology Transfer
MR	Quantitative Analysis of the Corridor Performance – Mobility
MOE	Measure of effectiveness
MPO	Metropolitan Planning Organization
MTS	Metropolitan Transit System
NCTCOG	North Central Texas Council of Governments
NCTD	North County Transit District
NTTA	North Texas Tollway Authority
O&M	Operation and maintenance
OES	Office of Emergency Services
PAMS	Portable activity measurement systems
PGBT	President George Bush Turnpike
PHT	Person-hours traveled
PMT	Person-miles traveled
RITA	Research and Innovative Technology Administration
S	Quantitative Analysis of the Corridor Performance – Safety
SANDAG	San Diego Association of Governments
SANTEC	San Diego Traffic Engineers' Council
SD SAFE	Diego County Service Authority for Freeway Emergencies
SOV	Single-occupant vehicle
SPF	Safety performance function
SR	State route
TECHCAP	Technical Assessment of Capability to Monitor, Control and Report
TR	Traveler Response
TxDOT	Texas Department of Transportation
UC-R	University of California, Riverside
UPA/CRD	Urban Partnership Agreements/Congestion Reduction Demonstration
U.S. DOT	U.S. Department of Transportation
VHT	Vehicle-hours traveled
VMT	Vehicle miles traveled

EXECUTIVE SUMMARY

This report presents the high-level framework for conducting the national evaluation of the United States Department of Transportation (U.S. DOT) Integrated Corridor Management (ICM) Initiative Demonstration Phase. The ICM Initiative is a joint effort of three U.S. DOT agencies—the Research and Innovative Technology Administration (RITA), Federal Highway Administration (FHWA), and Federal Transit Administration (FTA). The national evaluation contractor team is led by Battelle, with support from URS, Corporation, the University of Maryland, Eastern Research Group, Philip Tarnoff, and Athey Creek Consultants.

Integrated corridor management refers to a multi-agency, multi-modal approach intended to "load balancing"—improving the match between transportation demand and available corridor capacity—so as to maximize transportation efficiency and safety within a defined corridor. The logical next step in congestion management, ICM seeks to optimize existing transportation infrastructure along a corridor, making transportation investments go farther. ICM is intended to enable travelers to make informed travel decisions and dynamically shift modes during a trip; reduces travel time, delays, fuel consumption, emissions and incidents; and increases travel time reliability and predictability. The demonstration phase of the ICM program includes two real-world field deployments of specific ICM concepts that are the subject of the national evaluation, one focusing on the US-75 corridor in the Dallas region and one focusing on the I-15 corridor in the San Diego region.

The national evaluation will thoroughly investigate and document the impacts of the ICM deployments, including the implementation of specific agency operational capabilities and the traveler behavior, mobility, safety, air quality and benefit-cost impacts associated with the exercise of those capabilities. The evaluation will also explore the institutional and organizational issues and lessons associated with the two ICM deployments, always an important area and more so given ICM's inherent focus on agency coordination.

The U.S. DOT ICM Program

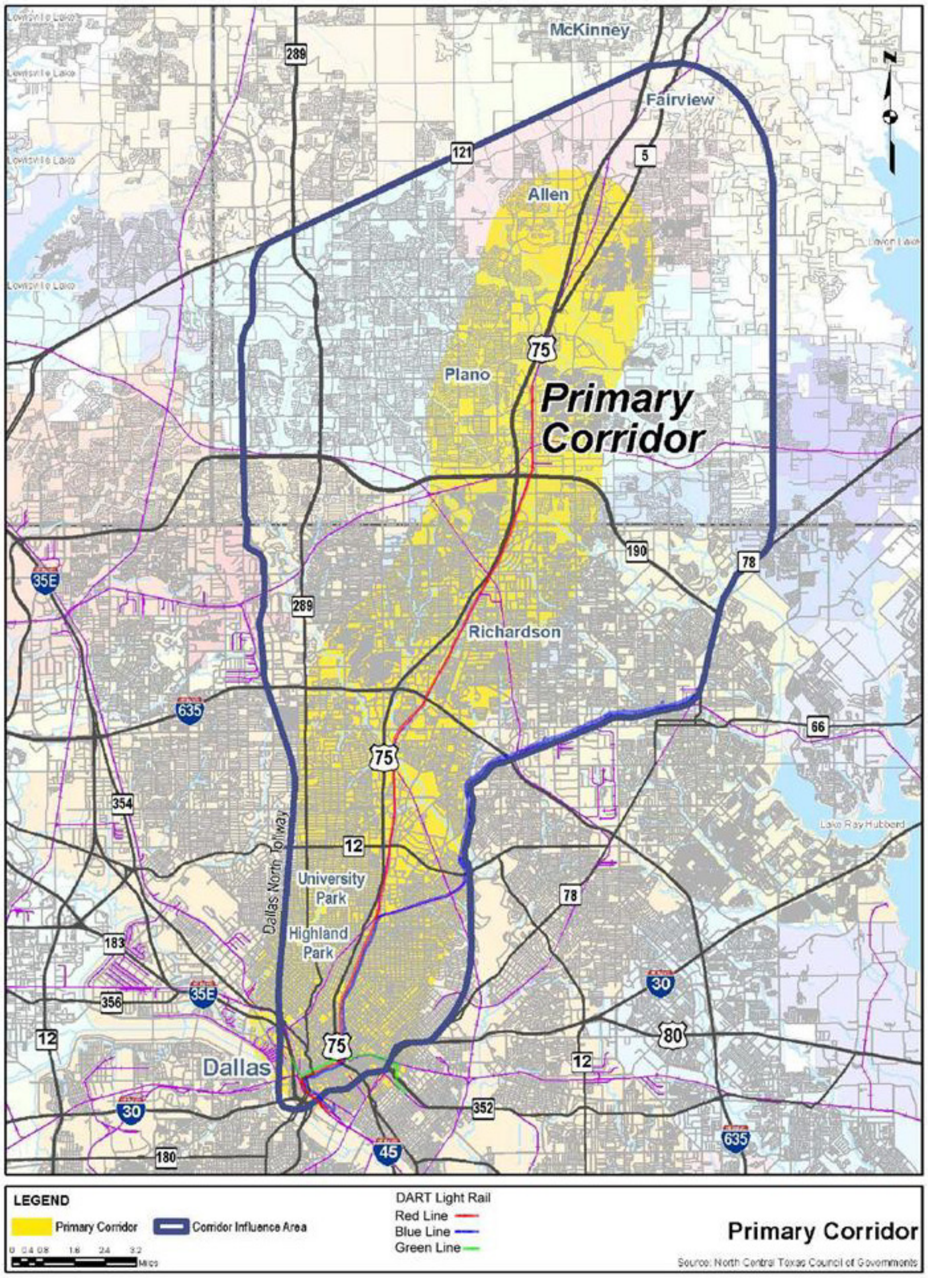
The objectives of the U.S. DOT ICM Initiative are:

1. 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.
2. Develop a toolbox of operational policies, cross-network operational strategies, integration requirements and methods, and analysis methodologies needed to implement effective ICM systems.
3. Demonstrate how proven and emerging ITS technologies can be used to coordinate the operations between separate corridor networks to increase the effective use of the total transportation capacity of the corridor.

The U.S. DOT selected eight Pioneer Sites to plan, design, model and demonstrate the benefits of ICM. Two of those sites—Dallas and San Diego—have received a total of about $14 million in Federal ICM deployment funding and will be the subjects of national evaluation. The Dallas and San Diego ICM deployments and this evaluation occur within Phase 3 of the U.S. DOT ICM Program. Previous phases included foundational research and development of Analysis, Modeling and Simulation (AMS) tools that are being exercised and refined in the Phase 3 evaluation. The AMS tools will be calibrated using evaluation results and will provide some data for the evaluation. Phase 4, which runs the duration of the ICM Initiative Program, focuses on knowledge and technology transfer.

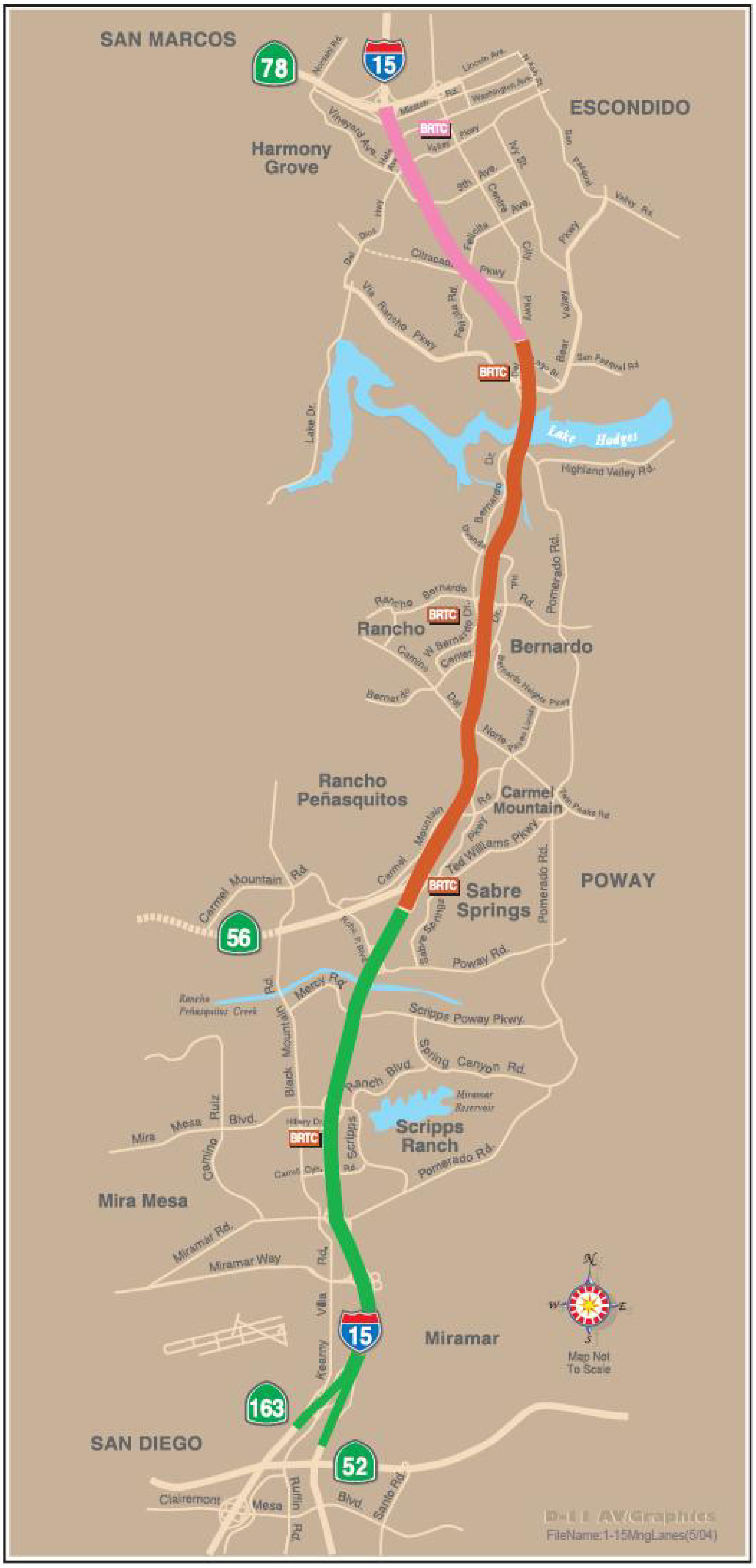
The Dallas and San Diego ICM Deployments

The Dallas ICM deployment focuses on the U.S.-75 corridor in the northeast portion of the region. The corridor includes high occupancy vehicle lanes in the U.S.-75 freeway, extensive frontage roads, parallel arterial streets and light rail transit and bus service. The San Diego ICM deployment focuses on the I-15 corridor in inland, north central San Diego County. The corridor includes a 16-mile, concurrent flow high-occupancy toll/managed lanes facility in the median of I-15, a ramp meter system and bus rapid transit. Figures ES-1 and ES-2 show the Dallas and San Diego ICM corridors.



DART and their ICM partners, June 30, 2010

Figure ES-1. U.S.-75 Corridor Boundaries



San Diego Association of Governments, January 2011

Figure ES-2. San Diego I-15 Corridor

Both sites are implementing center-to-center information sharing and distribution system enhancements (sharing among transportation operations agencies); new or enhanced means of corridor management across all networks, including shared control of some field devices, traveler information messages, and transit priority; additional field detection infrastructure; new or enhanced traveler information delivery mechanisms (e.g., a 511 system in Dallas); and decision support systems. Traveler information strategies emphasize providing travelers with information on operational conditions for all corridor networks and components, such as comparative travel times, parking space availability, incident information, and expected delays. Decision support systems (DSS) are among the most innovative aspects of the deployments in terms of technology; the other ICM elements focus mostly on enhancing existing, proven technologies and making significant enhancements to multi-modal agency coordination. The decision support systems include travel prediction capabilities and will be used by the sites to develop pre-planned response plans corresponding to a variety of common scenarios, including incidents, special events, construction or maintenance and severe weather. The sites will also be able to use their DSS in real time to modify pre-planned response plans and to develop and evaluate custom response plans. The evaluation is especially interested in the performance and value of the DSS.

The San Diego system is scheduled to become fully operational in February 2013. The Dallas ICM system is scheduled to become fully operational in April 2013.

National Evaluation Framework

The evaluation will investigate and document the investments made by both sites, including ICM-related changes in policies and procedures; document and evaluate the capabilities acquired through ICM deployment and how those capabilities were utilized; and assess the impacts of the deployments, including mobility, safety, air quality and overall benefit-cost. Institutional and organizational issues and lessons learned will also be investigated.

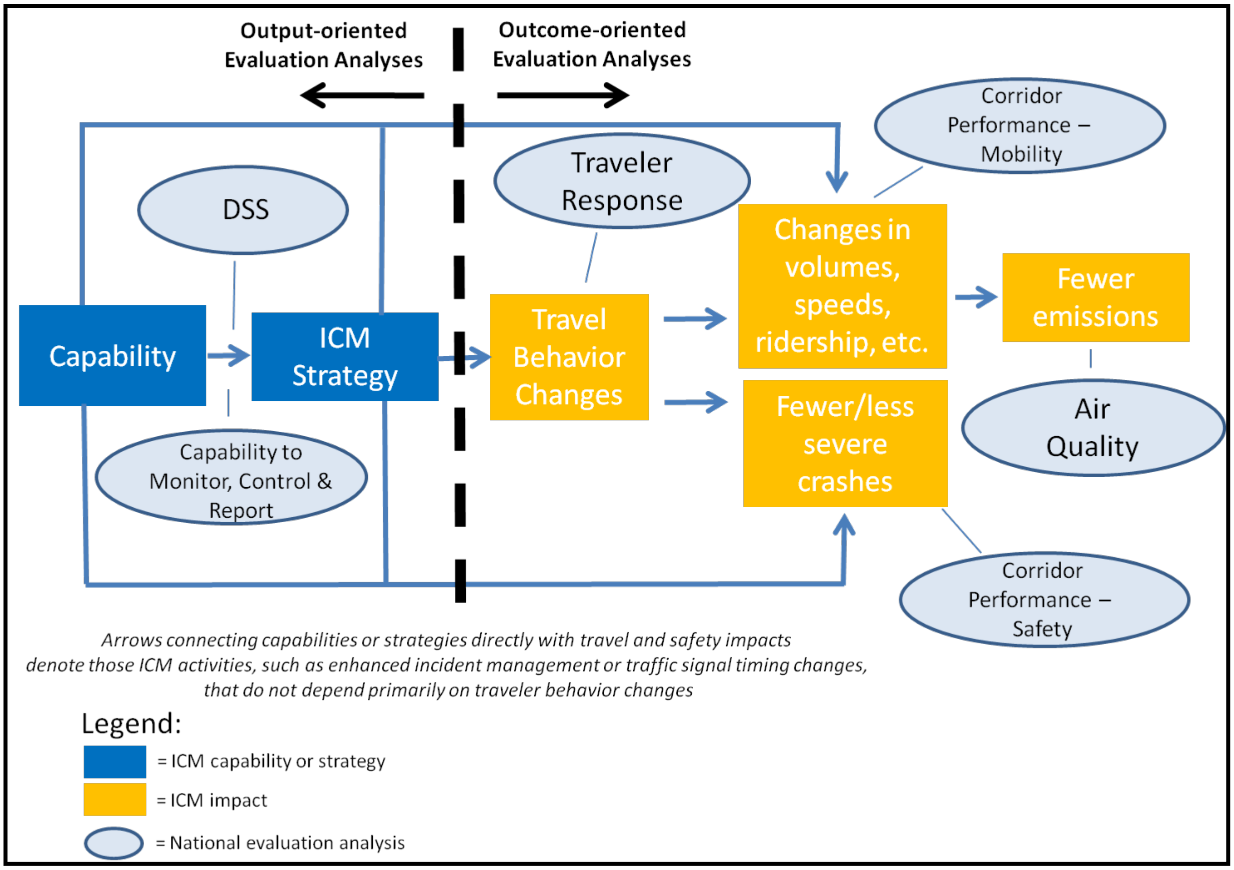
The evaluation will investigate seven broad hypotheses posed by U.S. DOT. The U.S. DOT hypotheses and the corresponding evaluation analysis areas are shown in Table ES-1. The evaluation includes an eighth analysis area that will investigate institutional and organizational issues and considerations, an especially important area since successful ICM is so reliant on agency coordination. 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").

Table ES-1. 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 the 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

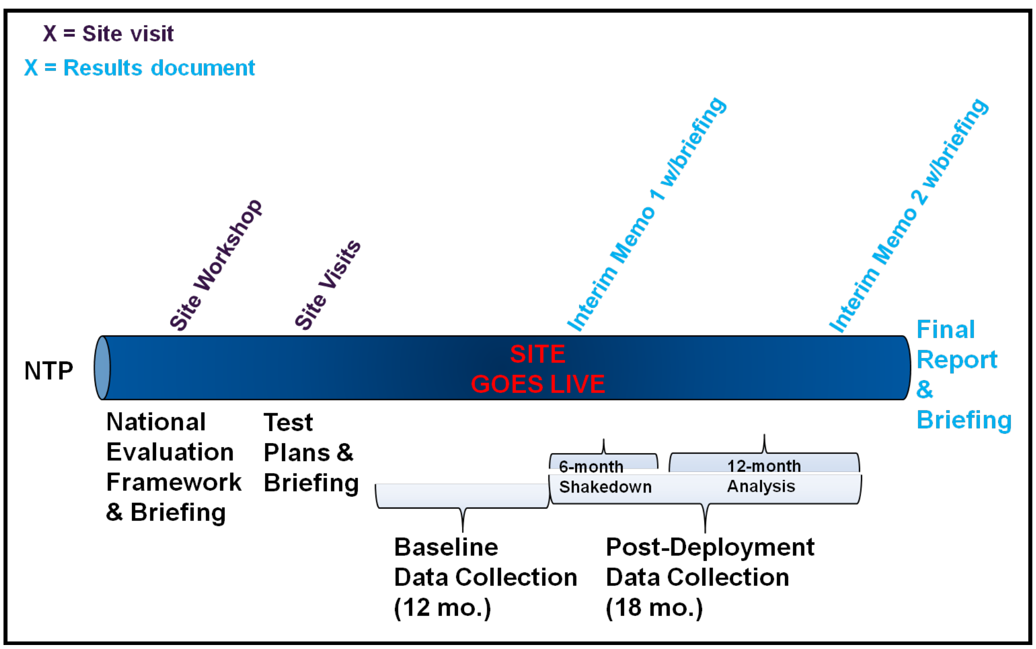
Battelle

Figure ES-3 shows how various evaluation analyses relate to the output and outcome components of the logic model. As shown in Figure ES-4, the evaluation includes a two-part planning phase consisting of this framework followed by more detailed, site-specific test plans for each analysis. The evaluation includes collection and analysis of 12 months of baseline (pre-ICM) and, following a 6-month shakedown period, 12 months of post-deployment data. Interim evaluation results will be presented in two interim memos, one focusing on baseline conditions and one on preliminary comparisons of baseline and post-deployment conditions. A final report will present the results from both sites as well as cross-cutting findings. Based on current expected "go live" dates for each deployment, Interim Tech Memo 1 is expected in May 2013, Interim Tech Memo 2 in October 2014, and the Final Report in April 2015.



Battelle, May 7, 2012

Figure ES-3. Relationship Between Evaluation Analyses and the Logic Model



Battelle, May 7, 2012

Figure ES-4. Sequence of Evaluation Activities

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1.0 INTRODUCTION

This report presents the high-level framework for conducting the national evaluation of the United States Department of Transportation (U.S. DOT) Integrated Corridor Management (ICM) Initiative Demonstration Phase. The ICM Initiative is a joint effort of three U.S. DOT agencies—the Research and Innovative Technology Administration (RITA), Federal Highway Administration (FHWA), and Federal Transit Administration (FTA). The national evaluation contractor team is led by Battelle, with support from URS Corporation, the University of Maryland, Eastern Research Group, Phillip Tarnoff, and Athey Creek Consultants.

Integrated corridor management refers to a multi-agency, multi-modal approach intended to "load balancing"—improving the match between transportation demand and available corridor capacity—so as to maximize transportation efficiency and safety within a defined corridor. The logical next step in congestion management, ICM seeks to optimize existing transportation infrastructure along a corridor, making transportation investments go farther. ICM is intended to enable travelers to make informed travel decisions and dynamically shift modes during a trip; reduces travel time, delays, fuel consumption, emissions and incidents; and increases travel time reliability and predictability. The demonstration phase of the ICM program includes the two real-world field deployments of specific ICM concepts that are the subject of the national evaluation, one focusing on the US-75 corridor in the Dallas region and one focusing on the I-15 corridor in the San Diego region.

The national evaluation will thoroughly investigate and document the impacts of the ICM deployments, including specific agency operational capabilities realized and the traveler behavior, mobility, safety, air quality and benefit-cost impacts associated with the exercise of those capabilities. The evaluation will also explore all of the institutional and organization issues and lessons associated with the two ICM deployments; always an important area and more so given the inherent ICM focus on agency coordination. This introduction chapter provides an overview of the U.S. DOT ICM Program, a high-level summary of the Dallas and San Diego deployments, a description of ICM Demonstration Phase roles and responsibilities, and discusses the national evaluation objectives and process.

The Dallas and San Diego deployment coalitions of course play a critical role as the deployers of the systems that are the subject of this evaluation. However, they also play a key role in collecting and transmitting to the national evaluation team most of the required evaluation data, as this evaluation places that responsibility primarily with the deployers. Key data collection activities which are the responsibility of the evaluators, rather than the deployers, include surveys, interviews and workshops with Dallas and San Diego ICM participants and stakeholders; AMS modeling results; and the traveler survey to be conducted at both sites by the Volpe National Transportation Systems Center with support from their survey contractor and from the national evaluation team.

1.1 The U.S. DOT ICM Program

This section includes substantial material (shown indented) including a number of direct quotes 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. In a number of instances, the original text has been revised slightly at the direction of U.S. DOT to update and/or correct.

> In March 2007, the Secretary of the U.S. Department of Transportation affirmed the department's commitment to a national initiative to manage highway, freight and aviation congestion, calling congestion one of the greatest threats to the nation's economy. The Secretary noted that businesses lose an estimated $200 billion per year due to freight bottlenecks; and drivers waste nearly 4 billion hours of time, and more than 2 billion gallons of fuel, in traffic jams each year. The greatest concentration of congestion is often along critical transportation corridors that link residential areas with business centers, sports arenas and shopping areas. New road construction alone will not solve the growing problem of congestion—travel demand on our nation's roadways is outpacing new freeway capacity by a factor of five.
>
> ICM is a promising tool in the congestion management toolbox that seeks to optimize the use of existing infrastructure assets and leverage unused capacity along our nation's urban corridors. With ICM, transportation professionals manage the transportation corridor as a multimodal system—rather than taking the more traditional approach of managing individual assets.
>
> ICM enables transportation managers to optimize use of available infrastructure by directing travelers to underutilized capacity in a transportation corridor. Strategies include motorists shifting their trip departure times, routes, or modal choices, or transportation managers dynamically adjusting capacity by changing metering rates at entrance ramps or adjusting traffic signal timings 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 effective ICM systems.

- Demonstrate how proven and emerging ITS technologies can be used to coordinate the operations between separate corridor networks to increase the effective use of the total transportation capacity of the corridor.

The U.S. DOT selected eight Pioneer Sites to plan, design, model and demonstrate the benefits of ICM:

- Dallas, Texas
- Houston, Texas
- Minneapolis, Minnesota
- Montgomery County, Maryland
- Oakland, California
- San Antonio, Texas
- San Diego, California
- Seattle, Washington"

Two of these sites—Dallas and San Diego—have received Federal funds for deployment and are being evaluated in the national evaluation. Although the U.S. DOT ICM program will continue to monitor progress at the other sites and share information with the transportation community, the national evaluation does not include explicit consideration of the other six Pioneer Sites.

The USDOT's ICM Initiative is occurring in four phases:

- **Phase 1: Foundational Research** – This phase included research into the current state of corridor management in the United States as well as leading examples of ICM-like practices around the world; initial feasibility research; and the development of technical guidance documents, including the general concept of operations for ICM designed to help sites in the development of their own ICM concept of operations.
- **Phase 2: Corridor Tools, Strategies and Integration –** USDOT developed a framework to model, simulate and analyze ICM strategies. It is working with the Pioneer Sites to deploy and test various ICM components such as standards, interfaces and management schemes.
- **Phase 3: Corridor Site Development, Analysis and Demonstration** – U.S. DOT selected three Pioneer Sites to analyze and model their ICM strategies; and will fund demonstration and evaluation of up to two approaches that appear to offer the greatest potential. Phase 3 consists of three stages: 1) Concept Development – FY07-FY08 (all eight ICM sites developed concepts of operation and requirements documents; 2) Modeling – FY09-FY10 (the Dallas, Minneapolis and San Diego proposed ICM systems were modeled); and 3) Demonstration and Evaluation – FY10-FY13 – (Dallas and San Diego will demonstrate their ICM strategies and data from the demonstrations will be used to refine the 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 USDOT's ICM Initiative into a suite of useful multimedia resources designed to equip transportation practitioners in corridors around the country to implement ICM.

This evaluation focuses on Phase 3, which includes the field demonstration phase of the Dallas and San Diego ICM projects. Figure 1-1 summarizes the timing of the four ICM Initiative phases.

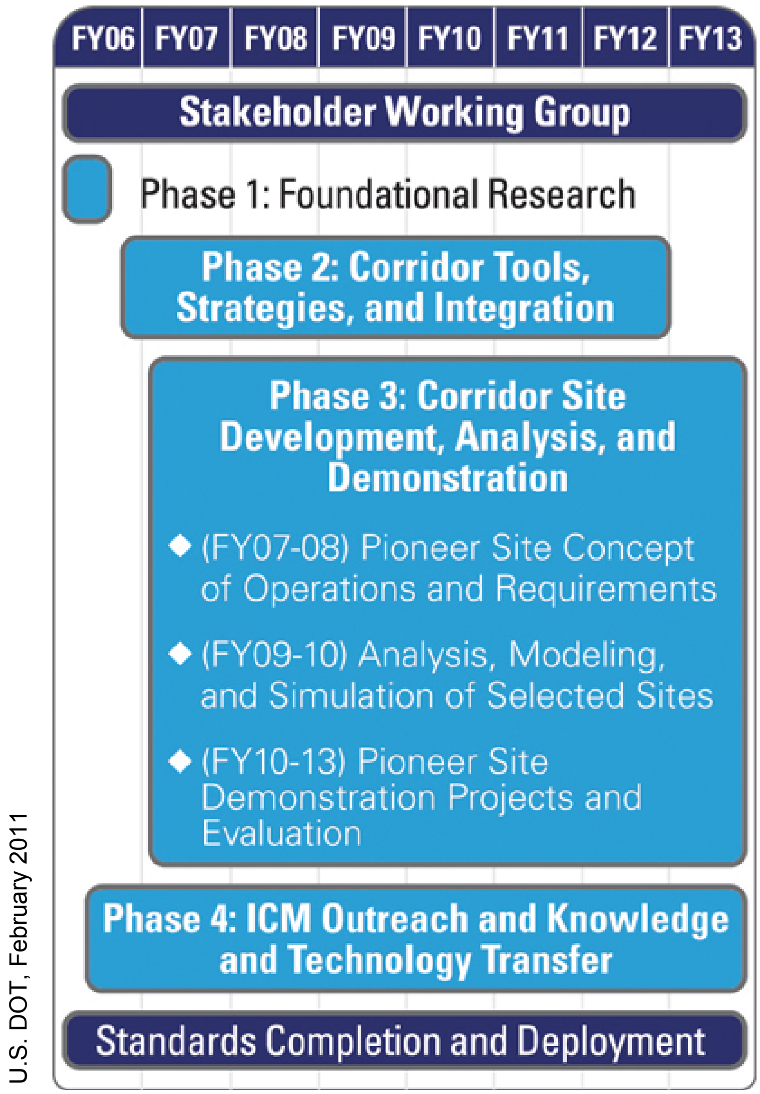


Figure 1-1. ICM Initiative Phases

Analysis, modeling and simulation (AMS) is an important on-going ICM Initiative activity and one that is very relevant to the evaluation. Phase 2 of the ICM Initiative included development of AMS tools which were used by the sites in their identification and evaluation of candidate ICM strategies. Phase 3, Stage 2 AMS activities included modeling the proposed Dallas and San Diego ICM deployments. The AMS work continues in Phase 3, Stage 3 in which the tools are being further calibrated and validated and used by the sites to refine their ICM strategies and in which the AMS tools will be further calibrated and validated based on key evaluation results.

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, as elaborated in Section 3.5 and the analysis approaches presented in Chapter 5, 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.

In addition to the national evaluation team, the FHWA, FTA and RITA are supported in their Phase 3 ICM activities by the following contractors:

- Program Technical Support – Noblis
- AMS – Cambridge Systematics
- KTT – SAIC.

1.2 The Dallas and San Diego ICM Demonstration Phase Deployments

The information in this section (shown indented) has been excerpted directly from the article "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 and at the direction of U.S. DOT some updates or corrections have been made to this material.

This section provides brief, high-level summaries of the Dallas and San Diego ICM deployments. Additional information, including corridor maps, is presented in Chapter 2. Both sites are implementing many of the same strategies, including decision support systems (DSS) that will allow the sites to develop pre-planned response plans for various common conditions and select and modify response plans in real-time based on traffic predictions. The DSS represent a particularly innovative aspect of the ICM deployments and, as elaborated later in this document, constitute a special focus of the evaluation.

1.2.1 Dallas

The U.S. 75 project is a collaborative effort led by Dallas Area Rapid Transit (DART) in collaboration with USDOT; the cities of Dallas, Plano, Richardson, and University Park; the town of Highland Park; North Central Texas Council of Governments (NCTCOG); North Texas Tollway Authority (NTTA); and the Texas Department of Transportation (TxDOT).

U.S. 75 is a north-south radial corridor that serves commuter, commercial, and regional trips, and is the primary connector from downtown Dallas to the cities to the north. Weekday mainline traffic volumes reach 250,000 vehicles, with another 30,000 vehicles on the frontage roads. The corridor has 167 miles (269 kilometers) of arterial roadways.

The U.S. 75 corridor currently has two concurrent flow-managed, high-occupancy vehicle (HOV) lanes, light rail, bus service, and park-and-ride lots. The corridor sees recurring congestion and a significant number of freeway incidents. Light rail on the DART red line is running at 75 percent capacity, and arterial streets are near capacity during peak periods and are affected by two choke points at the U.S. 75/Lyndon B. Johnson Freeway (I-635) interchange and U.S. 75/President George Bush Turnpike interchange.

DART and the regional stakeholders will contribute $3 million to the $8.3 million project, which will use a DSS to predict travel conditions 30 minutes into the future. Those predictions will facilitate diversion of traffic from U.S. 75 to other routes during freeway incidents and special events. Through 511 telephone and web-based alerts, travelers will have access to real-time information about traffic, public transit, and expected travel times. Another goal of the Dallas ICM system demonstration is to improve incident management through interagency communication and coordinated response.

Specific practices that the Dallas team intends to employ include the following:

- Provide comparative travel times between various points of interest to the public via the 511 system for the freeway, arterial streets, and light-rail transit line, as well as real-time and planned events status and weather conditions. Operating agencies plan to have real-time status of all facilities within the ICM corridor.
- Use simulations to assess current conditions and to predict travel conditions to improve traffic operators' responses.
- Implement interdependent response plans among agencies.
- Divert traffic to strategic arterials and frontage roads with improved traffic signal timing response plans that can adjust signal timing in response to real-time traffic demands.
- Shift travelers to the light-rail system during major incidents on the freeway.

1.2.2 San Diego

The I-15 project is a collaboration led by the San Diego Association of Governments (SANDAG), along with USDOT, the California Department of Transportation, Metropolitan Transit System, North County Transit District, and the cities of San Diego, Poway, and Escondido, in addition to private sector support. The goals are to augment technical management, software and systems development, and cutting-edge innovation.

The San Diego ICM corridor includes the portion of I-15, a north-south facility, from S.R. 78 in the north to the S.R. 163 interchange in the south. 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 16-mile, concurrent flow high-occupancy toll/managed lanes facility, the "I-15 Express Lanes." Currently, this facility varies from two to four lanes but is being expanded and will be a consistent four lanes in 2012, prior to the San Diego ICM system "go live." Approximately 30,000 vehicles use the I-15 Express Lanes during weekdays, and the corridor experiences recurring congestion.

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 HOV and high-occupancy tolling (HOT) lanes, bus rapid transit, and other options.

Examples of practices the San Diego team intends to employ include the following:

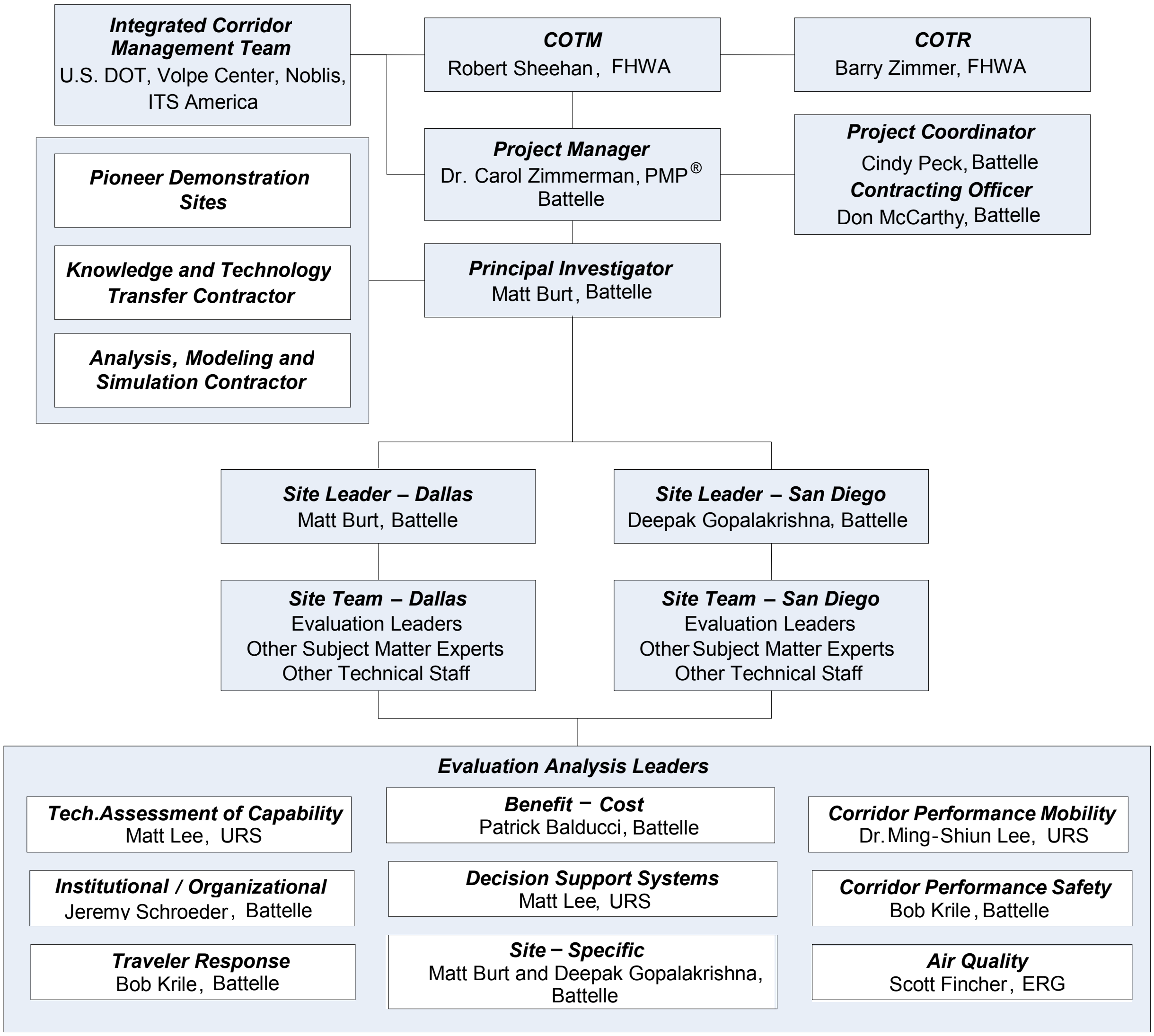
- Provide corridor users with the operational condition of all corridor networks and components, such as comparative travel times, parking space availability, incident information, and expected delays.
- Use a decision support system with real-time simulation, predictive algorithms, and analysis modeling.
- 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.

1.3 National Evaluation Objectives and Process

The national evaluation of the Dallas and San Diego Demonstration Phase deployments is intended to thoroughly investigate and document what the sites implemented, the capabilities achieved by the participating agencies, how those capabilities were exercised, and the direct and indirect impacts of the ICM activities. Specifically, the evaluation will address a number of evaluation hypotheses in the following areas:

- The implementation of ICM will:
  - Improve situational awareness
  - Enhance response and control
  - Better inform travelers
  - Improve corridor performance
- The implementation of ICM will have a positive or no effect on:
  - Air quality
  - Safety
  - Have benefits greater than costs
- Decision support systems provide a useful and effective tool for ICM project managers through their 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.

The organization of the Battelle evaluation team is shown in Figure 1-2. The team includes an overall project manager, a principal investigator responsible for the project technical work, a designated evaluation site leader at each site, and subject matter experts that will lead each of the evaluation analyses. The evaluation analysis, including eight confirmed analyses that will be performed in a similar fashion at both sites (addressing hypotheses in the areas noted above) and, if the need becomes apparent as evaluation planning proceeds, one or more “site-specific” analyses to address any issues not contained within the eight standard analyses. In addition to representatives of FHWA, FTA and RITA headquarters personnel, U.S. DOT representation on the ICM evaluation include the Volpe Center and FHWA Resource Center personnel. The U.S. DOT ICM Management Team includes a core team of four U.S. DOT representatives. Mr. Brian Cronin, P.E., serves as the RITA/JPO ICM Program Manager. Mr. Steve Mortensen serves as the FTA ICM Program Manager and is the U.S. DOT evaluation site leader for the Dallas ICM national evaluation. Mr. Robert Sheehan, P.E., PTOE, is a Transportation Specialist with the FHWA Office of Operations – Transportation Management and serves as national evaluation Contracting Officer Technical Manager (COTM) and U.S. DOT San Diego evaluation site leader. Mr. Dale Thompson is a Transportation Research Specialist in the RITA Joint Program Office and, as Research and Development ICM Research Coordinator, Dale is responsible for leading and coordinating the research activities in the Phase 1 ICM Analysis, Simulation and Modeling and Phase 3 Technical Integration efforts. The USDOT ICM Management Team is supported by Noblis and ITS America.



Battelle, May 7, 2012

Figure 1-2. Evaluation Team Organization

Figure 1-3 summarizes the sequence of major evaluation activities and deliverables. Table 1-1 provides a more detailed breakdown of tasks and associated deliverables and presents specific, anticipated schedule information. The schedule information shown in Table 1-1 is the latest, official, U.S. DOT-approved schedule at the time of publication. As the sites' deployment schedules continue to evolve, the evaluation schedule will adjust. The sites' plans to deploy some of their ICM elements in a phased manner over the months leading up to the overall ICMS "go live" date creates challenges to baseline data collection that are discussed in Section 3.6. The sites' ICM schedules are presented in Section 2.4.

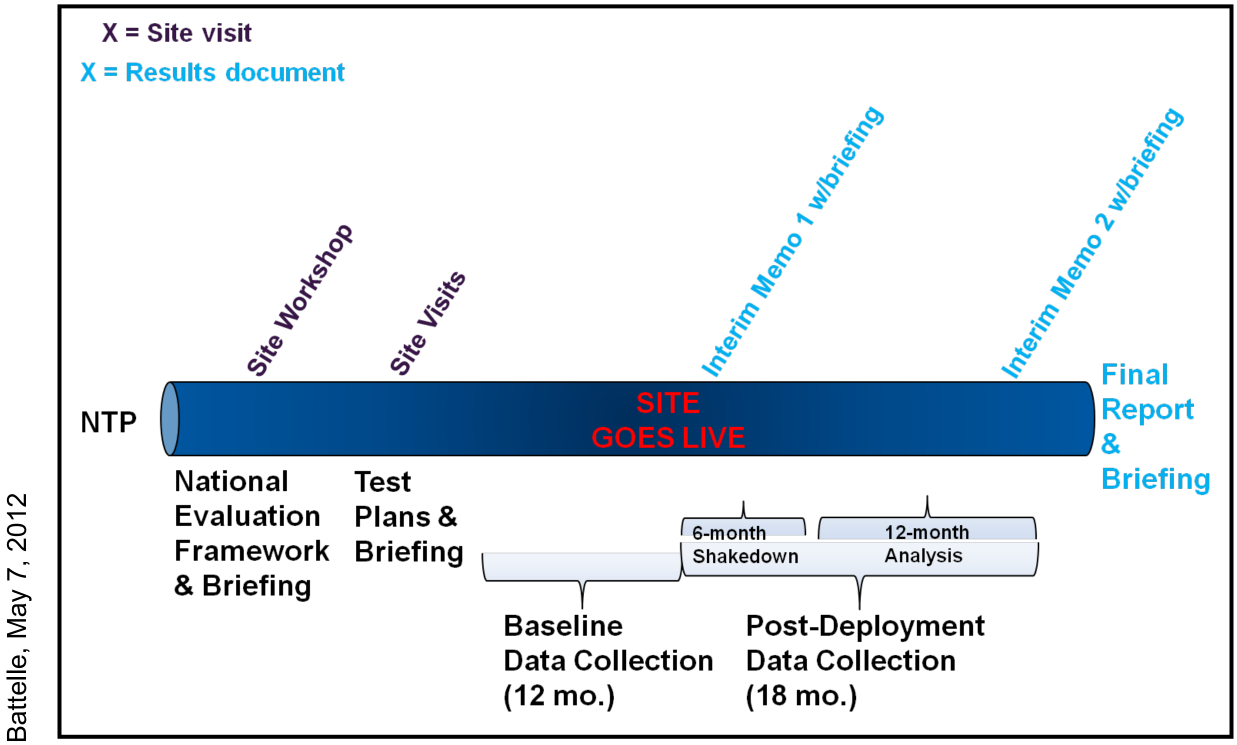


Figure 1-3. Sequence of Evaluation Activities

Table 1-1. ICM Evaluation Tasks, Deliverables and Schedule

Task	Deliverable	Deliverable Date
1.1	Kickoff meeting slides	September 14, 2010
1.2	Project management plan • Draft • Final • Quarterly updates	• Draft, September 15, 2010 • November 2, 2010 • Quarterly after kickoff
1.3	Monthly reports	15th of each month
1.4	Quarterly report slides	Quarterly after kickoff
1.5	Biweekly teleconference reports	Biweekly
2.1	Evaluation framework • Draft • Briefing slides • Final	• February 28, 2011 • March 30, 2011 • May 25, 2011
2.2	Site-specific test plans • Draft • Briefing slides • Final	• Nov. 17, 2011 (Dallas), Feb. 24, 2012 (San Diego) • Dec. 19, 2011 (Dallas), Mar. 6, 2012 (San Diego) • Feb. 17, 2012 (Dallas), Mar. 27, 2012 (San Diego)
3.1	Baseline data collected and stored in repository	Dallas: Jan. 4, 2012 – Jan. 1, 2013 San Diego: Feb. 17, 2012 – Feb. 13, 2013
3.2	Post-deployment data collected and stored in repository	Dallas: Jan. 2, 2013 – July 1, 2014 San Diego: Feb. 15, 2013 – Aug. 14, 2014
4.1	Interim technical memo I • Draft • Briefing slides • Final	• March 14, 2013 • April 28, 2013 • May 24, 2013
4.2	Interim technical memo II • Draft • Briefing slides • Final	• September 11, 2014 • September 25, 2014 • October 31, 2014
5.0	Final report draft	January 29, 2015
5.2	Final report briefing slides	March 12, 2015
5.3	Final report final version	April 23, 2015
6.1	6 workshops • 2 white papers per workshop (draft and final) • 2 sets presentation slides per workshop (draft and final)	March 23, 2011 – March 18, 2015
6.2	6 conferences • 2 white papers per conference (draft and final) • 2 sets of presentation slides per conference (draft and final)	June 2, 2011 – May 11, 2015
7.0	508-compliant documents (approx. 74 plans, memos, reports, white papers, briefings)	February 2, 2012 – July 5, 2015

Battelle

The evaluation planning phase of this project is represented by Tasks 2.1 and 2.1 in Table 1-1, which encompass this evaluation framework and the site-specific test plans that will follow. For each site, one test plan will be developed for each evaluation analysis. Whereas this framework focuses on the hypotheses and overall analysis approaches, the site-specific test plans will specify and finalize the required data elements and sources, specific mechanisms for collecting the data, timing of data collection and analysis activities, and detailed analytical approaches. As the test plans formalize all of the data collection activities, it is important to complete all, or at least the most critical portions, of test plan development prior to the beginning of data collection. As indicated in Figure 1-3, 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—one shortly after the end of the baseline data collection effort and one shortly after the end of the post-deployment data collection effort—and a single final report documenting the findings at both sites as well as cross-cutting results. As indicated along the top of Figure 1-3, two formal site visits are planned by the evaluation team to each site as part of evaluation planning: one during national evaluation framework development (site workshops conducted in December 2010 in Dallas and January 2011 in San Diego) and test planning-related visits in the spring or early summer of 2011. Additional data collection trips will be made by various members of the evaluation team during baseline and post-deployment data collection.

1.4 Report Organization

The remainder of this report is organized into the following chapters:

- Chapter 2 – describes the ICM Demonstration Phase Deployments, including the corridors and their travel characteristics, the site team organizations, and the specific ICM strategies to be deployed.
- Chapter 3 – describes the national evaluation breadth, organization and issues, including a high-level discussion of challenges, data sources, and timing issues.
- Chapter 4 – discusses how the "logic model" introduced in Chapter 3 is being applied through the evaluation analyses.
- Chapter 5 – presents the framework for each of 8 evaluation analyses.
- Chapter 6 – next steps.

2.0 ICM PHASE 3 DEPLOYMENTS

This chapter describes the ICM Phase 3 deployments at each site, including the corridors and their characteristics, the organization of each site's team, the strategies to be implemented, and the deployment schedules.

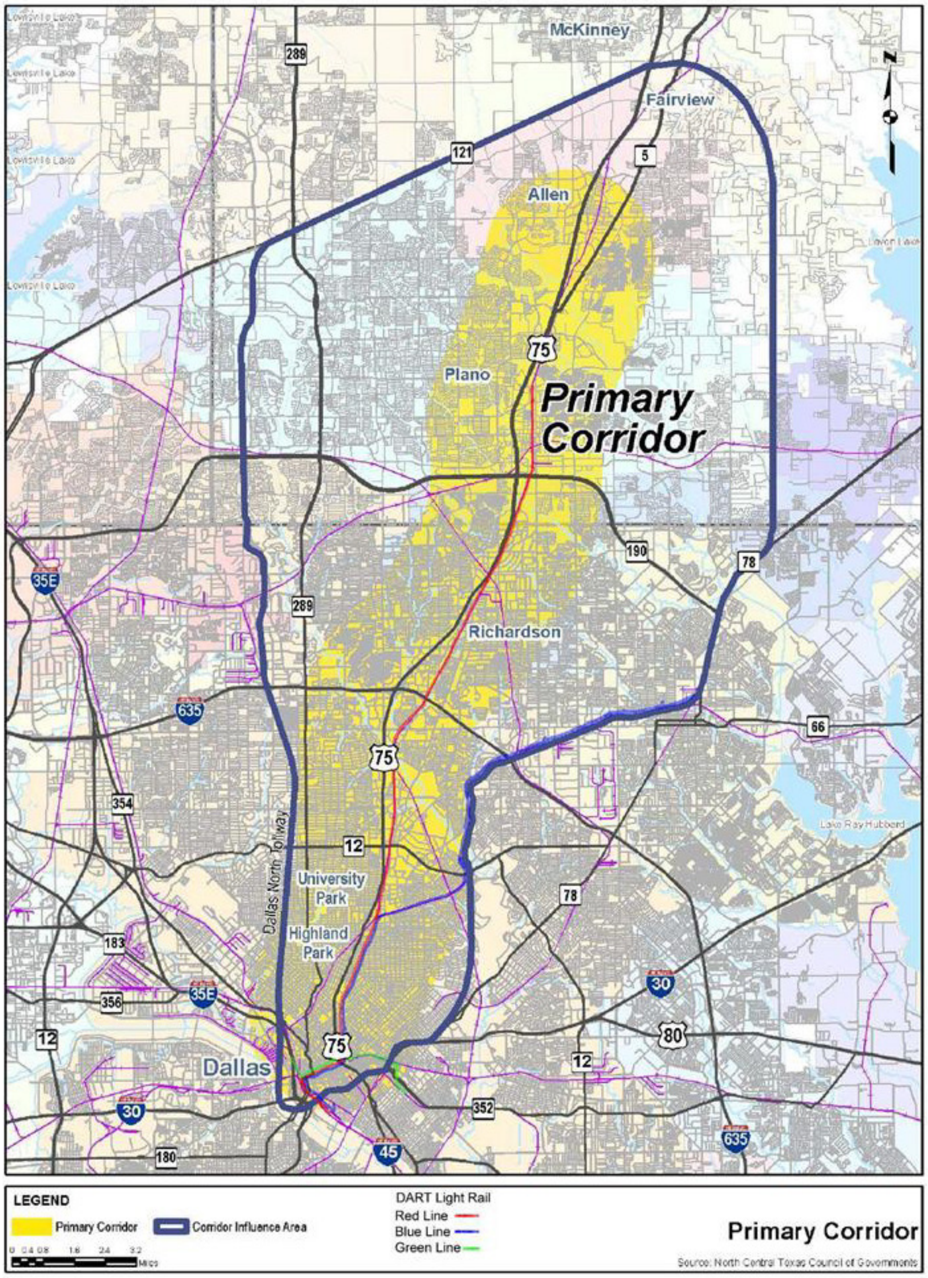
2.1 The ICM Corridors

This section describes the ICM corridors at each site, including the transportation system and travel characteristics.

2.1.1 U.S.-75 Corridor in Dallas

The information in this section, including Figure 2-1 which depicts the immediate U.S.-75 Corridor, is excerpted in its entirety from the Dallas deployment team's Concept of Operations document (DART in association with their ICM partners; June 30, 2010). A few revisions have been made to update or correct the text.

> The Corridor for the Dallas Pioneer Project is the U.S.-75 Corridor (also known as the North Central Expressway Corridor). This Corridor is a major north-south radial Corridor connecting downtown Dallas with many of the suburbs and cities north of Dallas. The primary Corridor consists of a freeway, continuous frontage roads, light-rail line, transit bus service, park-and-ride lots, major regional arterial streets, toll roads, bike trails, and intelligent transportation systems. A concurrent-flow, high-occupancy vehicle lane in the Corridor, opened in December 2007 and significant expansion of the intelligent transportation systems for the freeway and arterials street systems are programmed.
>
> The U.S.-75 Corridor has been defined at two levels. The immediate Corridor consists of the primary freeway Corridor and light-rail line Corridor and all arterial streets within approximately two miles of the freeway, as described above. The primary Corridor is highlighted in Figure 2-1. In addition, a full "travelshed" influence area has been defined that includes additional alternate modes and routes that may be affected by a major incident or event. The travelshed area is generally bound by the downtown to the south, the Dallas North Tollway to the west, SH 121 to the north, and a combination of arterials streets and the DART Blue Line to the east. This travelshed influence area is also shown in Figure 2-1.
>
> This U.S.-75 Corridor contains Dallas' first major freeway completed around 1950. This section of freeway was totally reconstructed with cantilevered frontage roads over the depressed freeway section and re-opened in 1999 with a minimum of eight general-purpose lanes. The freeway mainlanes carry over 250,000 vehicles a day, with another 20,000-30,000 of the frontage roads.



DART and their ICM partners, June 30, 2010

Figure 2-1. U.S.-75 Corridor Boundaries

The Corridor also contains the first light-rail line constructed in Dallas, part of the 20-mile DART starter system, opened in 1996. The Red Line now expands into cities of Richardson and Plano and passes next to the cities of Highland Park and University Park. This facility operates partially at-grade and partially grade-separated through deep-bored tunnels under U.S.-75. There is also another rail line, the Blue Line, which operates in the U.S.-75 Corridor near downtown Dallas and extends along the eastern edge of the Corridor boundary. In the downtown, there is also a connection from these lines to the regional commuter rail line that extends to downtown Fort Worth.

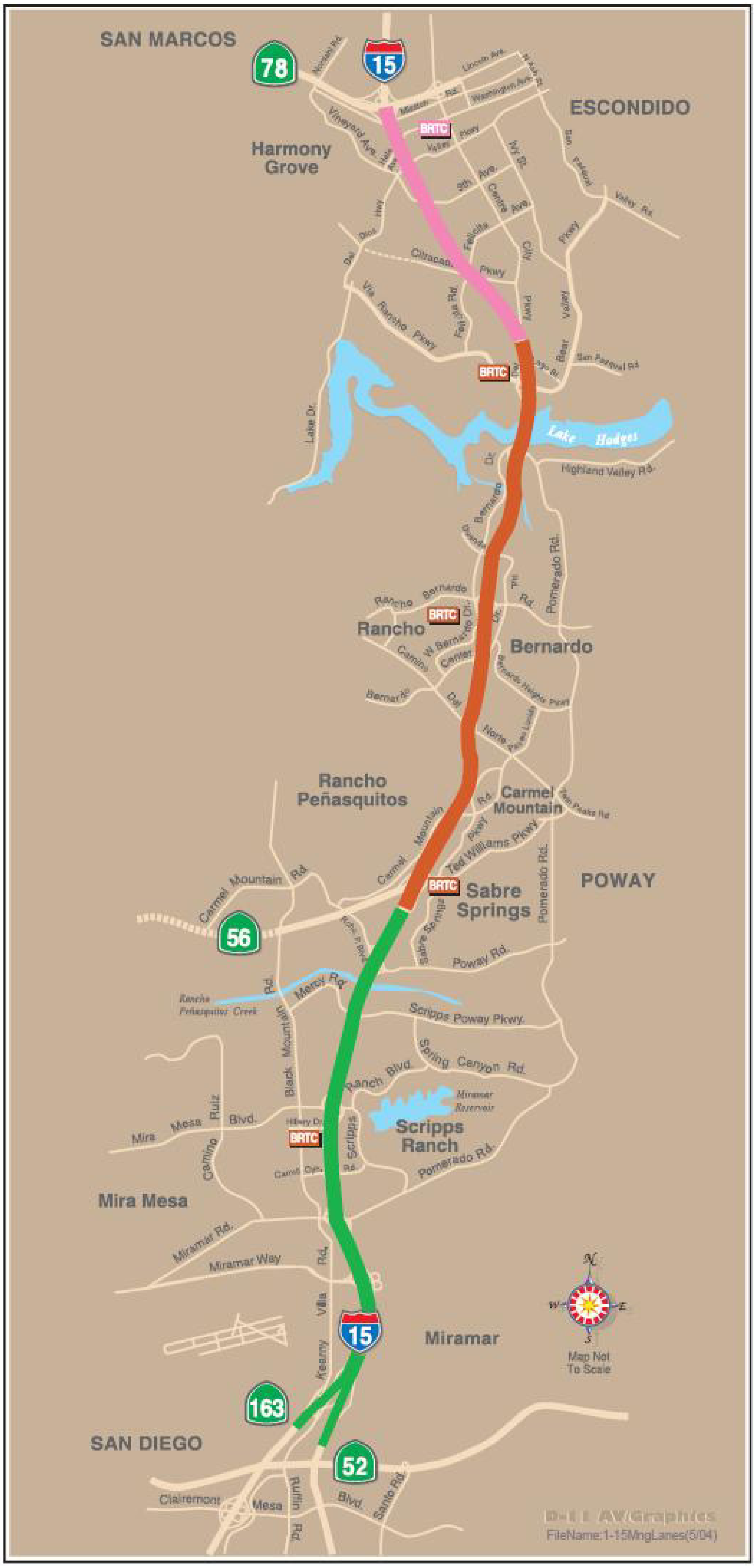
The Corridor serves commuting trips into downtown Dallas via the freeway, bus routes, light-rail line, and arterial streets. There are also a significant number of reverse commuters traveling to commercial and retail developments in the northern cities and neighborhoods. The Corridor also serves significant regional traffic during off-peak periods. The freeway is a continuation of Interstate 45; and thus, it also serves interstate traffic into Oklahoma. The Corridor is also a major evacuation route and experienced significant volumes during the Hurricane Rita evacuation in 2005.

There are three major freeway interchanges in the Corridor. U.S.-75 has an interchange with the downtown freeway network connecting to Interstate 45 and Interstate 35E. At the midpoint in the Corridor, there is a newly constructed interchange with Interstate 635. In the northern section, there is an interchange with the President George Bush Turnpike (PGBT).

2.1.2 I-15 Corridor in San Diego

The information in this section, including Figure 2-2 which depicts the I-15 corridor, is excerpted in its entirety from the San Diego deployment team's "Draft Operations and Maintenance Plan, Volume 1 – Operations Plan," version 1200 (San Diego Association of Governments and Kimley-Horn and Associates; January 19, 2011). A few revisions have been made to update or correct the text.

The I-15 corridor is a regionally significant north-south highway in inland San Diego County, serving local, regional, and interregional travel. The corridor is a heavily utilized regional commuter route, connecting communities in northern San Diego County with major regional employment centers. It encompasses three cities (San Diego, Poway, and Escondido). The I-15 corridor is situated within a major interregional goods movement corridor connecting Mexico with Riverside and San Bernardino counties, as well as Las Vegas, Nevada. The corridor currently has a 16-mile, concurrent flow high-occupancy toll/managed lanes facility, the "I-15 Express Lanes." Currently, this facility varies from two to four lanes but is being expanded and will be a consistent four lanes in 2012, prior to the San Diego ICM system "go live." The I-15 corridor also includes a portion of state route (SR) 163 from SR 52 to I-15 in the City of San Diego. The Express Lanes corridor is a critical component of I-15 serving both as free-flowing travel lanes for HOV and toll-paying single-occupancy vehicle (SOV) customers and as fixed guideway for one of the region's most successful bus systems. The I-15 corridor has experienced increasing levels of traffic demand and widened peak travel periods for decades, causing travelers to experience increased travel delay and congestion. However, the recent construction of additional free lanes, auxiliary lanes, operational improvements, and the expansion of managed Express Lanes have helped to alleviate some of the congestion within the I-15 corridor.



San Diego Association of Governments, January 2011

Figure 2-2. San Diego I-15 Corridor

The following characteristics are currently observable in the I-15 Corridor:

- Corridor bottlenecks primarily related to the on-going construction of new Express Lanes that will be fully opened to traffic by 2012.
- Travel times for northbound travelers increase by 50 percent during the p.m. peak travel. Travel times in the southbound direction have increased by 400 percent.
- A burgeoning Premium Express Bus service serving the I-15 corridor consisting of five routes and operating 12 buses per hour during peak periods between corridor bedroom communities and the region's two largest employment centers. The addition of the Express Lanes/BRT system will increase the capacity and performance of this existing transit service.
- The I-15 express lanes have noticeably reduced congestion in the South Segment of the corridor for both a.m. and p.m. peak periods.

2.2 Site Team Organization

This section identifies the local ICM deployment partners at each site.

2.2.1 Dallas

The Dallas ICM Phase 3 proposal (DART in association with its partners; December 15, 2009) identifies the following partners:

- Dallas Area Rapid Transit
- City of Dallas
- Town of Highland Park
- North Central Texas Council of Governments
- North Texas Tollway Authority
- City of Plano
- City of Richardson
- Texas Department of Transportation
- City of University Park
- Texas Transportation Institute
- Southern Methodist University
- University of Texas – Arlington
- Telvent
- FHWA
- FTA
- RITA.

DART and their ICM partners, June 30, 2010

Figure 2-3 from the Dallas team's Draft Project Management Plan[1] presents the Dallas ICM team project organizational structure. As indicated in Figure 2-3, DART is serving as the overall project management organization under the leadership of Mr. Koorosh Olyai who coordinates both with a diverse group of project participants and with four major supporting managers who focus on various modes (roadways and transit), policy and programming and Texas Department of Transportation operations. Telvent is serving as the lead program consultant. The Texas Transportation Institute, University of Texas – Arlington and Southern Methodist University are providing major support in the area of the DSS.

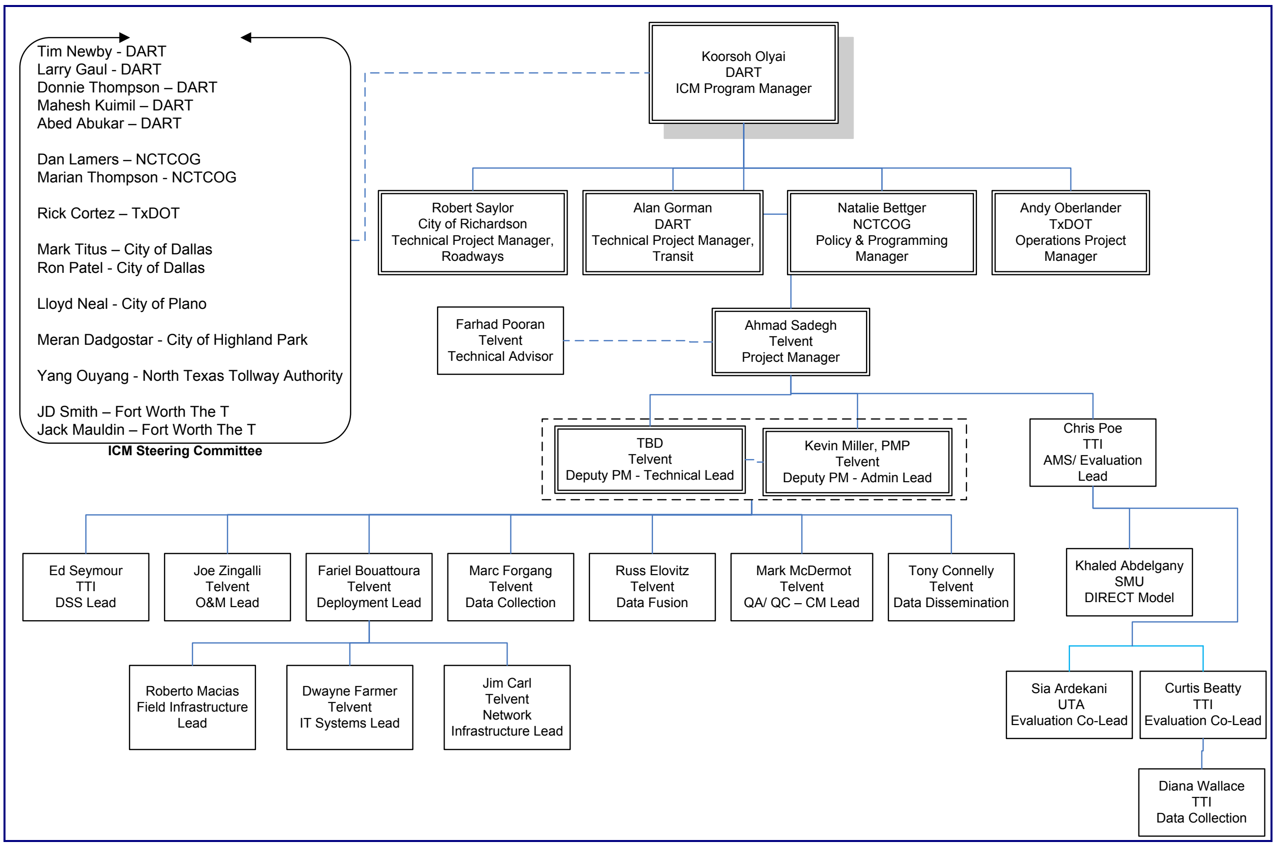


Figure 2-3. Dallas ICM Team Project Organization

[1] Draft Project Management Plan, version 2.0, DART, October 15, 2009.

2.2.2 San Diego

The San Diego 1-15 Corridor stakeholders are identified in the site's Phase 3 proposal as consisting of the following:

- San Diego Association of Governments (SANDAG), including the San Diego Traffic Engineers' Council (SANTEC), and Intelligent Transportation Systems Chief Executive Officer (ITS CEO) Group
- California Department of Transportation (Caltrans)
- California Highway Patrol (CHP)
- Metropolitan Transit System (MTS)
- North County Transit District (NCTD)
- San Diego County Service Authority for Freeway Emergencies (SD SAFE)
- City of San Diego
- City of Poway
- City of Escondido
- County of San Diego Office of Emergency Services (OES)
- Department of Homeland Security (DHS)
- FHWA
- FTA
- RITA.

Figure 2-4, from the San Diego Draft Project Management Plan[2] depicts the San Diego ICM high-level organizational structure. SANDAG serves as the overall ICM program manager, under the leadership of Mr. Samuel Johnson, who coordinates with a group of operating agency ICM partners. The technical work is led by two SANDAG co-project managers who are supported by Kimley-Horn and Associates for overall management of project delivery, evaluation, operations; and by a team led by Delcan for the system design, integration, building and testing.

This section presents the evaluation team's understanding of the ICM strategies that are planned by each site. This understanding is based on: review of the sites' Concept of Operations and System Requirement documents, Analysis, Modeling and Simulation documents, the San Diego Draft Operations and Maintenance Plan (version 1200, January 19, 2011); day-long evaluation workshop discussions with both sites—December 15, 2010 in Dallas and January 12, 2011 in San Diego; and additional discussions following the submittal of the draft version of this evaluation framework. The remainder of this section summarizes the evaluation team's understanding of each sites' ICM deployment plans, first in the form of a high-level summary of major approaches and then with a tabular listing of specific strategies.

[2] San Diego Draft Project Management Plan, version 2100, SANDAG, May 20, 2010.

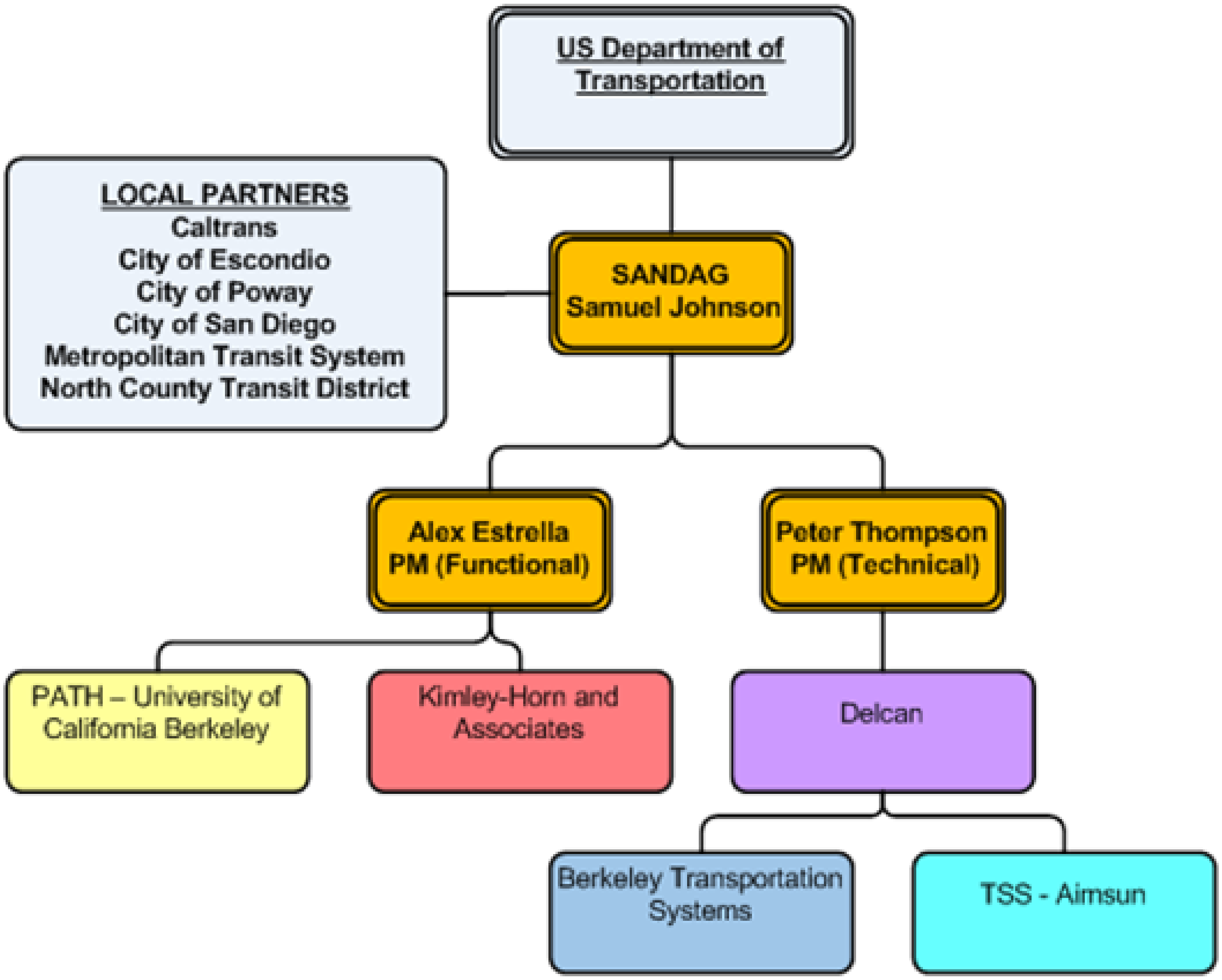


Figure 2-4. San Diego ICM Project Organization Chart

2.3 ICM Strategies

2.3.1 Summary of Sites' ICM Deployment Plans

Both sites' ICM deployments share many common strategies and components, with "load balancing" being a focus. Load balancing in the ICM context refers to multi-modal, multi-agency coordination of corridor operations in real-time to spread transportation demand over the available capacity, including the modal elements—freeways, arterial streets, and transit. This balancing includes changing the timing of trips. The overall objective of load-balancing is to maximize overall corridor people-moving efficiency and safety.

The sites' ICM deployment plans flow from their overall ICM goals. Each site's goals, as identified in their Phase 3 proposals, are shown in Table 2-1.

Table 2-1. Dallas and San Diego ICM Project Goals

<table>
<tr><th>Dallas</th><th>San Diego</th></tr>
<tr><td>

Improve Incident Management
Provide a corridor-wide and integrated approach to the management of incidents, events, and emergencies that occur within the corridor or that otherwise impact the operation of the corridor, including planning, detection and verification, response and information sharing, such that the corridor returns back to “normal.”
Enable Intermodal Travel Decisions
Travelers must be provided with a holistic view of the corridor and its operation through the delivery of timely, accurate and reliable multimodal information, which then allows travelers to make informed choices regarding departure time, mode and route of travel. In some instances, the information will recommend travelers to utilize a specific mode or network. Advertising and marketing to travelers over time will allow a greater understanding of the modes available to them.
Increase Corridor Throughput
The agencies within the corridor have done much to increase the throughput of their individual networks both from a supply and operations point of view, and will continue to do so. The integrated corridor perspective builds on these network initiatives, managing delays on a corridor basis, utilizing any spare capacity within the corridor, and coordinating the junctions and interfaces between networks, in order to optimize the overall throughput of the corridor.
Improve Travel Time Reliability
The transportation agencies within the corridor have done much to increase the mobility and reliability of their individual networks, and will continue to do so. The integrated corridor perspective builds on these network initiatives, managing delays on a corridor basis, utilizing any spare capacity within the corridor, and coordinating the junctions and interfaces between networks, thereby providing a multimodal transportation system that adequately meets customer expectations for travel time predictability.

</td><td>

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

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Dallas ICM Phase 3 Proposal (DART in association with their partners, December 15, 2009) and
San Diego ICM Phase 3 Proposal (SANDAG in association with their partners, May 28, 2009)

The major components and approaches associated with each site's ICM deployment include the following:

- **Decision support systems.** Both sites are developing software systems that will process a large volume of incoming data on transportation information (demand, network performance, capacity, operational status), identify problems, and recommend one or more actions ("response plans") to transportation system operators. In the case of multiple, simultaneous problems, the DSS are expected to "prioritize" the problems, either explicitly by recommending response options targeted to the most critical problem, or implicitly, in which the recommendation of responses reflect an overall "best fit" response given all identified problems. A key component of the DSS is a predictive (modeling) function that will allow the systems to take into consideration forecasted conditions, e.g., 30 minutes out, in developing and recommending responses, including forecasts of the results of candidate responses. Transportation operators will review the recommended plans and electronically share the selected plan (if any plan is selected) with their partner agencies which will either confirm and implement or reject the plan. The DSS will be used both pre-event—preparing standard response plans associated with a wide range of operating conditions and scenarios—and in real-time. The DSS represent a dramatic change relative to existing methods used at both sites (and throughout the country) where little or no automation is utilized by most transportation operators to develop, evaluate and modify transportation operations strategies. The sites' decision support systems are a particular focus of the evaluation because of this dramatic change they represent and because of the pioneering nature of the DSS technology. Table 2-2 provides additional information on DSS functionality at both sites.

Table 2-2. DSS Functionality Detail by Site

Dallas	San Diego
• **Modularization of Response Plan Recommendation Functionality and Predictive Functionality.** Dallas has explicitly separated the functionality required to select candidate response plans based on real-time conditions from the functionality associated with predicting future conditions. The former functionality resides in the Expert System DSS subsystem and the latter resides in the Prediction subsystem. These functions have been modularized so that the DSS will still be able to recommend response plans in the event that the mesoscopic traffic model used in the Prediction sub-system is not able to run faster than real-time, that is, to not only monitor current conditions but also to forecast conditions X minutes into the future. Dallas is anticipating their Predictive subsystem will ultimately be capable of running faster than real-time but they need to complete the design and testing phases of Stage 3. • **Real-time Monitoring of Transportation System Conditions.** The real-time data is collected by the ICMS Data Fusion subsystem. The Expert System subsystem of the Dallas DSS will monitor conditions from the Data Fusion subsystem in real-time and, based on key real-time system performance indicators, select one or more pre-defined, proposed response plans for consideration by the ICM Coordinator. • **Prediction and Prioritization of Emerging Transportation System Problems.** The Dallas ICMS will continuously monitor conditions. When events such as significant changes in demand, incidents (planned or not planned), or inclement weather occur, the Dallas DSS will initiate an analysis for possible operational strategies to improve corridor operation. The analysis of operational strategies is planned to include a prediction of future conditions under possible strategies. The Dallas ICMS is not currently planned to continuously predict future conditions. The Predictive subsystem is only executed as part of an evaluation of possible strategies. Although it is possible that the Dallas ICMS may be used in such a capacity at some point within or beyond the evaluation period, it is not an explicit design objective of the Dallas DSS to continuously predict conditions or anticipate developing problems. The Dallas ICMS, will however, have to account for multiple events occurring in the corridor and be able to prioritize which events need to be addressed or assess the interaction of strategies to different events. • **Prediction of the Impact/Performance of Response Plans.** The Prediction subsystem of the Dallas DSS will be capable of being used “on the fly” any time during an event to determine whether the net impacts/benefits of a candidate response plan recommended to the ICM Coordinator by the Expert System will be positive given current transportation system conditions and expected travel demand X minutes into the future. That is, prediction of the impacts of a response plan will be used in the decision of whether to implement a candidate response plan recommended by the Expert System. Further, if it is found that the Prediction subsystem is able to operate in faster-than-real-time mode—that is predict conditions X minutes into the future—the selection of response plans by the Expert System subsystem (and potentially the refinement or re-selection of response plans over the course of a long event) will incorporate predictions of transportation conditions and/or response plan impacts X minutes into the future.	• **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 DMS signing strategies and incident checklists. The heart of the DSS subsystem within the ICMS is the ability to analyze collected data, ascertain abnormal or scheduled events, determine appropriate responses, and suggest a set of actions that collectively form a “Response Plan.” The Response Plan may be manually or automatically generated, but if automatically generated, will include the capability for human operator review and modification. This is particularly critical for field device (i.e., DMS and camera) control actions. • **Real-time Monitoring of Transportation System Conditions through the DATA-HUB (IMTMS).** The DSS – DATA HUB takes data received from participating agencies and provides fused data to participating agencies as either Hypertext Transfer Protocol (HTTP) Web pages or 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. • **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 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, 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 2-5 minutes.

- **Enhanced information sharing among agencies.** A foundational, enabling strategy at both sites is to enhance the number of agencies that can access common information sources for real-time transportation conditions. The concept is that the ability to respond and to coordinate activities on a multi-agency, multi-modal, corridor level depends on the ability of all of the key transportation operators not only to understand both the real-time operational status and performance of their own assets but also those of their partner agencies. Both sites currently share information to some degree and have infrastructure in place to support sharing—SmartNET in Dallas and the Intermodal Transportation Management System (IMTMS) in San Diego—but the ICM enhancements will significantly increase both the number of agencies sharing information and the types of information shared. This includes, at both sites, implementation or expansion of common incident reporting systems and asset (geographic information system-based) management systems and enhanced sharing of roadway maintenance and construction activities and schedule coordination. Other information-based strategies implemented at one or both sites include investing in additional data collection, such as filling gaps in arterial street coverage, especially travel time data, park-and-ride lot management systems that include detectors, and transit passenger counters. Finally, strategies in this general area of "sharing" include expansion of shared control of "passive" ITS devices, such as closed-circuit television (CCTV) cameras, i.e., camera selection and pan/tilt/zoom.
- **Enhanced sharing of "actionable" information with travelers to promote route, mode or temporal shifts.** Providing travelers information to change their behavior in ways that will contribute to load balancing—changing routes (diverting from one road to another), modes (from driving to transit), postponing their travel to less congested time periods, or even eliminating a trip such as by telecommuting—is a core strategy at both sites and a cornerstone of ICM. The key activities in this area include:
    - Adding new or enhancing existing traveler information dissemination channels. For example, Dallas is implementing an advanced traveler information system composed of a 511 telephone (interactive voice response) and website service and a personalized traveler information system (ALERT system) and installing dynamic message signs on arterial streets. Both sites are investigating enhanced information sharing with third-party traveler information providers.
    - Providing travelers with enhanced information; information that will more directly facilitate load balancing behavior change than the information currently available. This consists primarily of providing travelers with comparative information showing conditions—travel times in particular—on multiple, alternative transportation facilities and services. For example, dynamic message signs (DMS) on U.S.-75 in Dallas will indicate whether parking spaces are available at nearby Red Line light rail parking facilities. (The Dallas ICM deployment includes a parking management system for LRT lots). Shifting freeway traffic during major incidents onto arterial streets (e.g., from U.S.-75 onto Greenville Avenue in Dallas) and/or to transit (LRT in Dallas; bus rapid transit in San Diego) is a major objective of the actionable traveler information strategies at both sites.

- **Changes to transportation system supply (capacity).** Manipulation of transportation capacity along with the traveler information strategies described above (manipulation of demand) constitute the twin prongs of the "action" or "doing" part of the ICM deployments. The sites' DSS and information sharing/distribution strategies, on the other hand, are the foundational part of ICM; they help the operators decide what should be done and provide them tools for doing it. Along with this strategy, activities for changing capacity include:
  - Adjusting arterial street traffic signal timing to support freeway diversions (both sites).
  - Transit signal priority treatments (San Diego to continue current bus priority strategies and Dallas to implement new LRT priority in downtown Dallas to enable the addition of LRT vehicles during peak demand).
  - Adjusting ramp meter timing to support diversions to or from the freeway (San Diego).
  - Lane use modifications, namely the four configurable, managed (variably priced high-occupancy toll) lanes in the I-15 median in San Diego, where the operators will be able to implement directional configurations ranging from one to three lanes in either direction. Both sites will continue to exercise their current policies of removing high-occupancy vehicle lane occupancy requirements during major incidents.
  - In Dallas, additional LRT vehicles will be placed into service during peak demand and they are considering the use of temporary, supplemental parking lots (associated with commercial businesses) with bus "bridge" service shuttling travelers from the temporary lots to nearby transit stations.
  - Although an indirect manipulation of supply, both sites intend that the degradation in freeway carrying capacity associated with incidents will be decreased to some extent through speedier, more effective incident verification and response. This is enabled by improved information sharing among agencies. This improved verification and response is intended to contribute to reductions in overall "return to service" time by reducing the freeway vehicle queue build-up, and thus the time required to "flush" the queued traffic. Queue build-up is to be reduced by diverting traffic approaching the queue to other roads or modes.

The major distinctions in the strategies to be utilized by each site generally flow from the differences in their transportation systems:

- The Dallas corridor includes the Red Line LRT service whereas the I-15 in San Diego corridor will include extensive bus rapid transit (being implemented separately from and immediately prior to ICM).
- The Dallas corridor includes HOV lanes whereas the San Diego corridor includes concurrent flow HOT/managed lanes:
  - The San Diego corridor includes an existing two-lane managed lane system in the I-15 median (variably priced high occupancy tolling) that is being expanded to four lanes in advance of the ICM implementation. The deployers do 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, high-occupancy vehicle lanes located in the median, although, like San Diego, they do not expect ICM to impact their HOV occupancy requirement decisions.
    - Both sites currently lift HOV restrictions during major incidents.

- Both sites include major arterials that run parallel with the freeways but Dallas also includes an extensive frontage road system.
- 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 adaptive traffic signal control along the major parallel arterial, Greenville Avenue, through the Cities of Dallas, Richardson and Plano. 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.

It is expected that the various Dallas and 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. 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), in association with an unplanned event like a traffic incident.
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.

2.3.2 Specific ICM Strategies

Each site's specification and elaboration of ICM strategies for implementation has been driven by a "master menu" of potential ICM "approaches" and "strategies" that was developed by U.S. DOT during the Phase 1 Concept Development and Foundational Research of the ICM program. The approaches and strategies are presented in the "Task 5.2 – Operational

Approaches Draft Final Technical Memorandum" (December 22, 2005). That memorandum identified 47 specific, candidate ICM strategies organized into the following categories:

- Approach A – Information Sharing/Distribution
- Approach B – Improve Operational Efficiency of Network Junctions and Interfaces
- Approach C – Accommodate/Promote Cross-Network Route and Modal Shifts
  - Passive Network Shifts ("inform")
  - Promote Network Shifts ("instruct")
- Approach D – Manage Capacity-Demand Relationship Within Corridor – "Real-time"/Short-Term
  - Capacity Oriented
  - Demand Oriented
- Approach E – Manage Capacity-Demand Relationship Within Corridor – Long-Term
  - Capacity Oriented
  - Demand Oriented

Appendix A contains a table excerpted from the Operational Approaches Technical Memorandum, briefly describing each candidate, generic strategy.

Each site, in their Phase 3 proposals, identified which of these strategies they would include in the ICM deployments. This was done in two ways, first by listing the name of each ICM strategy from the foundational research and then by presenting various scenarios referencing which strategies would be associated with the scenario. Table 2-3 summarizes the evaluation team's understanding of which general ICM strategies are planned at each site. Note that the objective in Table 2-3 is to show which strategies the sites are introducing or significantly enhancing through their ICM deployments not to capture the full-range of their current and continuing transportation operations strategies. The evaluation team will monitor the status and specifics associated with the sites' ICM deployments as the evaluation and implementations move forward since a thorough understanding of exactly what is being implemented, how it will be operated, and what impacts are intended is critical to an effective evaluation. The sites' plans relative to the 47 strategies identified in the foundational research can be summarized as follows:

- There are <u>22</u> strategies that <u>neither</u> site plans to implement, including multi-modal electronic payment, transit hub connection protection, converting regular lanes to transit-only or emergency-only, modifying toll/HOT pricing, or modifying transit fares.

- There are <u>14</u> strategies that <u>both</u> sites are implementing, including most of the information sharing/distribution strategies.

- There are <u>13</u> strategies that only one of the two sites are implementing:
  - Dallas only:
    - Multi-agency/multi-network incident response teams
    - Access to corridor information (e.g., ATIS database) by information service providers (ISPs) and other value-added entities
    - Signal priority for transit (e.g., extended green times to buses that are operating behind schedule)

    - Modify transit priority parameters to accommodate more timely bus/light rail service on arterial
    - Providing real-time information on the number of parking spaces available in the park and ride facility
    - Add transit capacity by adjusting headways and number of vehicles
    - Add transit capacity by adding temporary new service, e.g., express bus service, "bus bridge" around rail outage/incident (see comment in Table 2-3; Dallas' plans in this area are not final yet)
    - Add capacity at parking lots – temporary lots (see comment in Table 2-3; Dallas' plans in this area are not final yet)
    - Modify HOV restrictions (increase number, make bus only)
  - San Diego only:
    - Coordination of operation between ramp meters and arterial traffic signals in close proximity
    - Modify ramp meter rates to accommodate traffic, including buses, shifting from arterial
    - Promote shifts between transit facilities via en-route traveler information devices (e.g., station message signs and public announcements) advising riders of outages and directing them to adjacent rail or bus service
    - Lane use control (reversible lanes/contra-flow)

2.4 ICM Site Schedules

Table 2-4 presents the latest available Dallas and San Diego ICM deployment schedules at the time of publication of this framework. Both sites schedules have changed over the course of the development of this framework and are likely to continue to change as design and implementation continues. Updated schedule information will be presented in the site-specific evaluation test plans.

Currently, Dallas expects the full ICM system to become operational in late November 2012, with San Diego following about two months later in January 2013. Both site schedules show, to varying extents, phased completion of individual project element builds, and the Dallas deployers indicate that some ICM system elements may become operational in a phased manner. As discussed in Section 3.6, phased implementation of ICM elements and/or strategies will have implications for the evaluation. As indicated in Table 2-4, if these deployment schedules are maintained, the full year of national evaluation post-deployment data collection will be complete in May 2014 in Dallas and July 2014 in San Diego.

Table 2-3. ICM Strategies Listing by Site

USDOT ICM Strategy (from Foundational Research)	Inclusion in Sites' Plans		Comments
	Dallas	San Diego	
Approach A: Information Sharing/Distribution			
Manual information sharing	X	X	
Automated information sharing (real-time data)	X	X	San Diego lists a single strategy covering both real-time data and video; Dallas separately identifies a strategy for video, referencing a regional video clearinghouse.
Automated information sharing (real-time video)	X	X	
Information clearinghouse/information exchange network between corridor networks/agencies	X	X	
Corridor-based advanced traveler information system (ATIS) database that provides information to travelers pre-trip	X	X	San Diego focuses strictly on 511; Dallas dropped the "…pre-trip" from this strategy.
En-route traveler information devices owned/operated by network agencies (e.g., DMS, 511, transit public announcement systems) being used to describe current operational conditions on another network(s) within the corridor	X	X	San Diego's en-route information strategy states simply "en-route traveler information."
Common incident reporting system and asset management (geographic information system "GIS") system	X	X	
Shared control of "passive" ITS devices, such as CCTV (i.e., camera selection, pan/tilt/zoom)			
Access to corridor information (e.g., ATIS database) by information service providers (ISPs) and other value-added entities	X		Not currently expected to be deployed in San Diego within the evaluation period.
(not included in the USDOT list) Archive historical data	X	X	
Approach B: Improve Operational Efficiency of Network Junctions & Interfaces			
Signal priority for transit (e.g., extended green times to buses that are operating behind schedule)	X		Signal priority for transit (e.g., extended green times to buses that are operating behind schedule) is an existing strategy for the San Diego ICM partners, but ICM is not funding any hardware and so far no significant change in operation of signal priority is expected as a result of ICM in San Diego.
Signal pre-emption / "best route" for emergency vehicles	X	X	Identified in Dallas Concept of Operations (pg. 77) but not discussed at workshop (no slide was included).
Multi-modal electronic payment			
Transit hub connection protection (holding one service while waiting for another service to arrive)			
Multi-agency / multi-network incident response teams / service patrols and training exercises	X		
Coordinated operation between ramp meters and arterial traffic signals in close proximity		X	

Table 2-3. ICM Strategies Listing by Site (Continued)

USDOT ICM Strategy (from Foundational Research)	Inclusion in Sites' Plans		Comments
	Dallas	San Diego	
Approach C: Accommodate/Promote Cross-Network Route & Modal Shifts – Passive Network Shifts ("inform")			
Modify arterial signal timing to accommodate traffic shifting from freeway	X	X	
Modify ramp metering rates to accommodate traffic, including buses, shifting from arterial		X	San Diego not including buses.
Modify transit priority parameters to accommodate more timely bus/light rail service on arterial	X		Not identified as a separate strategy in Dallas but presumably included in the broader "transit signal priority" strategy. Not currently expected to be deployed within the Stage III San Diego ICM project.
Approach C: Accommodate/Promote Cross-Network Route & Modal Shifts – Promote Network Shifts ("Instruct")			
Promote route shifts between roadways via en-route traveler information devices (e.g., DMS, HAR, "511") advising motorists of congestion ahead, directing them to adjacent freeways/arterials	X	X	The San Diego deployers did not specifically identify this at the evaluation workshop but it is presumed to be included.
Promote modal shifts from roadways to transit via en-route traveler information devices (e.g., DMS, HAR, "511") advising motorists of congestion ahead, direction them to high-capacity transit networks and providing real-time information on the number of parking spaces available in the park and ride facility	X	X	San Diego is not including the park and ride facility parking information portion of this strategy.
Promote shifts between transit facilities via en-route traveler information devices (e.g., station message signs and public announcements) advising riders of outages and directing them to adjacent rail or bus services		X	
Re-route buses around major incidents			
Approach D: Manage Capacity – Demand Relationship Within Corridor – "Real-time" / Short-Term – Capacity Oriented			
Lane use control (reversible lanes/contra-flow)		X	
Convert regular lanes to "transit-only" or "emergency-only"			
Add transit capacity by adjusting headways and number of vehicles	X		Dallas strategy focuses on LRT.
Add transit capacity by adding temporary new service (e.g., express bus service, "bus bridge" around rail outage/incident)	X		Dallas' plans for utilizing temporary LRT station parking are uncertain (they are doing a study to determine need, given their recent expansion of several lots). If the temporary lots are implemented bus service will be added to "bridge" the temporary parking locations and the LRT stations.
Add capacity at parking lots (temporary lots)	X		See comment immediately above.
Increase roadway capacity by opening HOV/HOT lanes/shoulders	X	X	
Modify HOV restrictions (increase number, make bus only)	X		
Restrict ramp access (metering rates, closures)			
Restrict/reroute commercial traffic			
Re-routing rail transit to alternative rail networks			

Table 2-3. ICM Strategies Listing by Site (Continued)

USDOT ICM Strategy (from Foundational Research)	Inclusion in Sites' Plans		Comments
	Dallas	San Diego	
Approach D: Manage Capacity – Demand Relationship Within Corridor – "Real-time" / Short-Term – Demand Oriented			
Variable speed limits (based on time of day, construction, weather conditions)			
Modify toll/HOT pricing			
Modify transit fares to encourage ridership			
Modify parking fees			.
Variable truck restrictions (lane, speed, route, time of day)			
Re-route thru-traffic (e.g., trucks) away from corridor			
Approach E: Manage Capacity-Demand Relationship Within Corridor – Long-Term – Capacity Oriented			
Low cost infrastructure improvements to cross-network linkages and junctions			
Scheduled closures for construction			
Coordinate scheduled maintenance and construction activities among corridor networks	X	X	
Approach E: Manage Capacity-Demand Relationship Within Corridor – Long-Term – Demand Oriented			
Guidelines for work hours during emergencies/special events			
Peak spreading			
Ride-sharing programs			
Expand transit capacity (permanent)			
Land use around BRT stations			
High-bandwidth development			

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Table 2-4. Site Schedules

Activity	Dallas	San Diego	
Complete Planning Phase	December 2010		November 2010
Complete Design Phase	November 2011		April 2012
Build Phase (complete unit testing):			
Video Sharing	February 2012	Multi-modal interfaces	June 2012
My 511	February 2012	Event modeling subsystem	June 2012
Mobile Web	April 2012	Decision support system & traffic prediction tool	June 2012
Parking Management Information	April 2012	Additional field element construction	January 2013
Transit Signal Priority	May 2012		
DART Data Portal	May 2012		
Arterial Street Monitoring System	May 2012		
Adaptive Signal System	May 2012		
Parking Management Information	March 2012		
Decision Support System	July 2012		
SmartNET/Smart Fusion (including all integration of new ICM data) IT Infrastructure	July 2012		
Complete Integration Testing	August 2012		
Complete Acceptance Testing	November 2012		January 2013
Operations Go Live	November 2012		January 2013
Complete Shakedown Period	May 2013		July 2013
Complete Evaluation One Year Operational Period	May 2014		July 2014

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3.0 NATIONAL EVALUATION BREADTH, ORGANIZATION AND ISSUES

This chapter describes the overall scope and scale of the national evaluation, discusses a number of core organizing principles, and highlights several important issues that are further discussed in Chapters 4 and 5.

3.1 U.S. DOT Evaluation Hypotheses

The U.S. DOT has established as the primary objective and analytical thrust of the ICM demonstration phase evaluation the testing of the eight "hypotheses" shown in Table 3-1. Many of these hypotheses actually contain a number of individual, discrete hypotheses and they have been decomposed in several of the evaluation analysis discussions in Chapter 5. 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. Listing a separate hypothesis for DSS reflects U.S. DOT's interest in explicitly and discretely assessing DSS performance.

Table 3-1. 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.
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.
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.
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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The evaluation scope of work developed by U.S. DOT included a ninth area of potential hypotheses, "site-specific hypotheses," which were envisioned to include any site-specific hypotheses that do not fit within one of the other eight U.S. DOT hypotheses that will be tested at both sites. To date, no site specific hypotheses have been identified, although they may be during the development of the detailed, site specific test plan documents and as the sites further develop their specific ICM-enabled operations strategies. Also, it is expected that as test plans are developed some of the individual evaluation hypotheses presented in Chapter 5 will be customized to reflect site specifics.

3.2 Evaluation Logic Model

As the U.S. DOT hypotheses provide the analytical focus and direction for the national evaluation, the concept of an evaluation "logic model" provides the fundamental analytical construct for hypothesis testing. The logic model is a standard approach being used throughout U.S. DOT's Intelligent Transportation System evaluation program. The model explicitly recognizes that the ultimate successes or shortcomings of a technology deployment are the end results of a long series of interdependent events and conditions—causes and effects—and stresses a step-wise approach in which each link in the cause-effect chain is investigated in the evaluation.

Figure 3-1 illustrates a highly simplified, generic logic model for ICM evaluation. The logic model categorizes the "series of events or conditions" or "cause-effect links" into three broad categories:

1. **Inputs** – the investments made by the deployers, including hardware, software, infrastructure, staff hires, training, development or revision of policies or procedures, memoranda of understanding, etc.
2. **Outputs** – measures describing how the investments are utilized, the capabilities they provide and how those capabilities are exercised, including outputs that reflect operators' utilization of the investments (e.g., the number of new or enhanced traveler information advisories operators are able to issue) and the direct outputs of technology systems, such as the improvement in data collected through new or enhanced sensors. As shown in Figure 3-1, ICM outputs—ways in which the system is utilized and the associated products—fall generally into the categories of manipulation of transportation system supply (e.g., modifying traffic signal timing to accommodate traffic diverted from a highly congested freeway segment) and demand, (e.g., providing travelers information that may result in their postponing their trip to a less congested time)
3. **Outcomes** – describe the impact of the investments on the performance of the transportation system, including traveler responses, traffic congestion and safety.

The arrangement of inputs, outputs and outcomes from left to right in Figure 3-1 reflects the sequence and relationships along the cause-effect chain. For example, outputs are only realized if the proper inputs are provided—that is, that the supporting investments are made. Breaking down outcomes into multiple "tiers" in Figure 3-1 demonstrates how within the broad category of outcomes, there can also be internal sequences and relationships. For example, the mobility or safety benefits that ultimately flow from changes in traveler behavior such as diverting to a less congested roadway are dependent on travelers being aware of and accessing the information needed to support their decision. The lines connecting outputs directly with mobility impacts signify that some ICM-enabled actions such as adjustment of traffic signal timing plans do not rely on traveler response; through manipulation of supply they produce mobility and safety outcomes directly.

The boxes along the bottom of Figure 3-1 show that a number of key assumptions or enabling conditions influence whether investments and associated outputs are successfully realized. For example, turn-over in agency leadership and the associated change in priorities could impact the ability to make investments or utilize and operate them as envisioned. Figure 3-1 also shows that there are also many "exogenous factors" that influence whether intended outcomes are realized and/or whether they can be measured and attributed to the investment. Exogenous factors are further discussed later in this chapter.

Finally, the reader should note that not all of the types of outcomes possible with ICM are represented in Figure 3-1. For example, air quality outcomes have been omitted as a simplification.

3.3 Analysis Areas

The investigation of the eight U.S. DOT evaluation hypotheses have been organized into eight evaluation "analyses." These analysis areas generally correlate very closely with the hypotheses, as shown in Table 3-2. A separate analysis has been identified for the investigation of institutional and organizational issues which relates to all of the U.S. DOT hypotheses in so much as the ability to achieve any of the intended ICM benefits depends upon successful institutional coordination and cooperation.

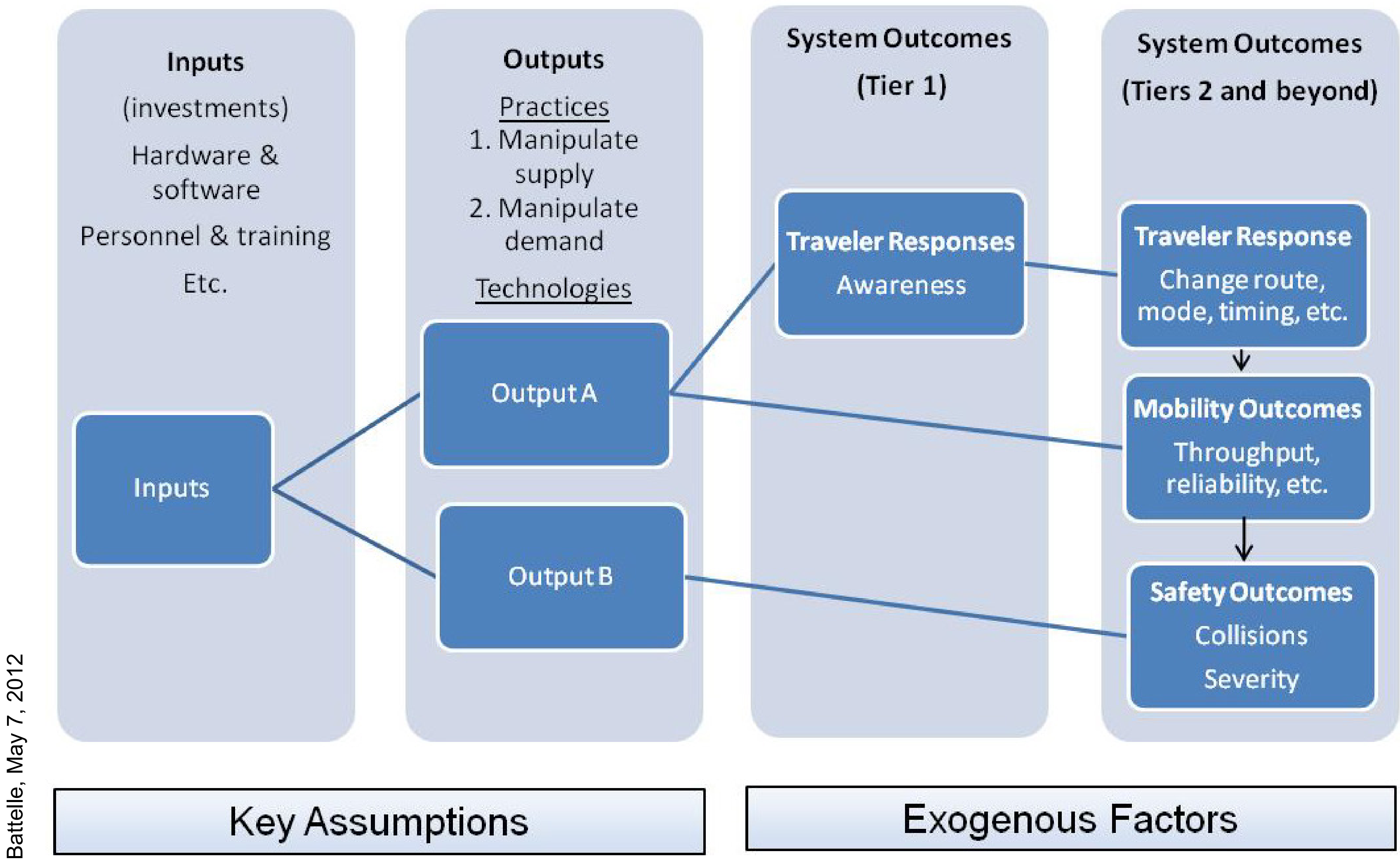

Figure 3-1. Generic Logic Model for Evaluation

Table 3-2. Relationship Between U.S. DOT Hypotheses and Evaluation Analyses

Evaluation Analysis Area	U.S.DOT Hypotheses
Technical Assessment of the Capability to Monitor, Control, and Report on the Status of the Corridor	• Improve Situational Awareness • Enhance Response and Control
Institutional and Organizational Analysis	• Applies to All (institutional/organization success is fundamental to the ability to achieve any of the intended impacts)
Traveler Response	• Better Inform Travelers • Enhance Response and Control
Quantitative Analysis of the Corridor Performance – Mobility	• Improve Corridor Performance
Quantitative Analysis of the Corridor Performance – Safety	• Positive or No Impact on Safety
Air Quality Analysis	• Positive or No Impact on Air Quality
Benefit-Cost Analysis	• Have Benefits Greater than Costs
Evaluation of DSS	• Provide a Useful and Effective Tool for ICM Project Managers

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There are explicit relationships between the organization of the analysis areas and the ICM evaluation logic model, as shown in Figure 3-2. Specifically, the analysis of outputs is the focus of the "Technical Assessment of Capability to Monitor, Control and Report" ("Technical Capability" or "TECHCAP") and DSS Analyses. These analyses focus on the capabilities acquired through the ICM investments and how those capabilities are exercised. The following analyses focus on the impacts of the sites' utilization of those capabilities: Traveler Response (TR), Quantitative Analysis of the Corridor Performance – Mobility ("Mobility," or "MR"), Quantitative Analysis of the Corridor Performance – Safety ("Safety," or "S"), and Air Quality (AQ). In the case of the Benefit-Cost Analysis, the "inputs" from the various other analyses (the investments made by the sites) represent the costs and the "outcomes" from the other analyses, e.g., travel time savings from the Mobility Analysis, represent the benefits.

The Institutional and Organizational analysis (I&O), not shown in Figure 3-2, is underlying or cross-cutting in the sense that it will help explain all of the evaluation results obtained across the logic model. But it is particularly associated with understanding of the "key assumptions" shown on Figure 3-1 and explaining how and why investments (inputs) were or were not fully realized. The Benefit-Cost Analysis (BCA) exists somewhat above and beyond the logic model and is also not shown in Figure 3-2. However, its connection to the logic model is that it will monetize the various outcomes generated through the application of the analysis and compare them to cost to implement and operate the ICM. This organization of analyses into those focusing on outputs (capabilities and their utilization) and outcomes (impacts on travelers and the transportation system) means that the understanding of the full impact of ICM strategies will entail consideration of results across various analyses. This concept is elaborated in Chapter 4. Also discussed in Chapter 4 is the fact that the documentation of inputs, although informed by some specific data collection in individual analyses, is accomplished primarily through the overall evaluation monitoring of the ICM planning, deployment and operations activities.

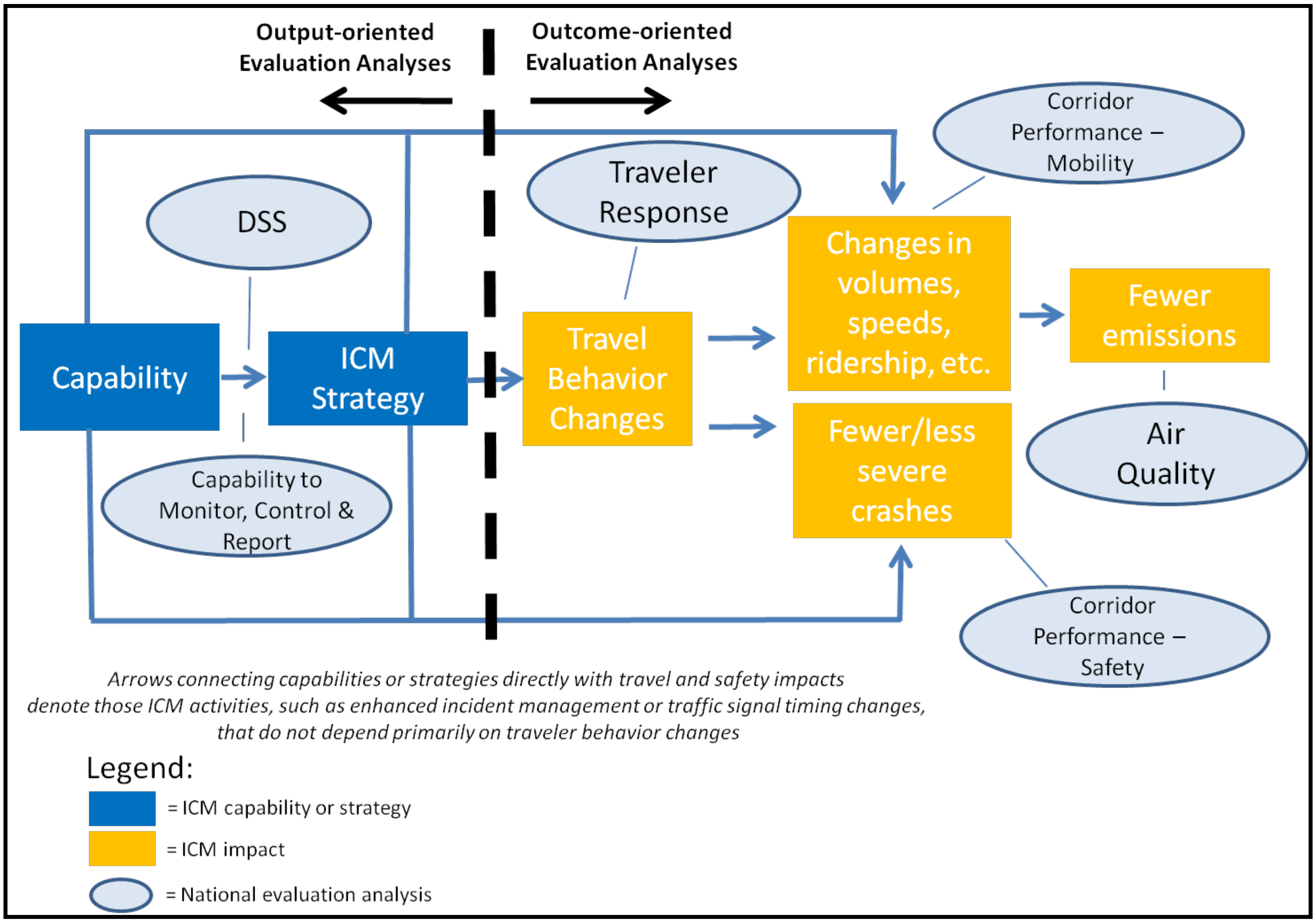

Figure 3-2. Relationship Between Evaluation Analyses and the Logic Model

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

- What was invested (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 deployments in terms of benefits versus costs (Benefit-Cost Analysis)?

3.4 Evaluation Challenges and Issues

The ICM evaluation presents a number of challenges that are unique to integrated corridor management, as well as challenges that are common to large transportation technology field deployments. Table 3-3 summarizes these challenges and the high-level approach to be used in the evaluation.

Table 3-3. ICM Evaluation Challenges and High-Level Evaluation Approaches

Challenge	Description	High-level Evaluation Approach
Capturing changes in what agencies <u>do</u> in addition to how <u>networks perform</u>	To a greater extent even than most ITS/operations deployments, ICM benefits depend on how agencies utilize capabilities.	• Include extensive assessment of both the <u>ultimate impacts</u> of ICM on traveler response and transportation system performance (outcomes) as well as the enhanced <u>operational capabilities</u> realized through ICM implementation (outputs) and how and why those capabilities were or were not fully utilized by the ICM operators. • The evaluation will utilize extensive field data, surveys and ICM AMS tools (modeling) to document traveler response and system performance. In addition, extensive data focusing on the operator and control center will be collected, including system data showing how the ICM capabilities were utilized and interviews and observations of operators.
The importance (and challenge) of assessing DSS performance	Unlike many evaluations, the performance of a specific technology—DSS—is a key part of this evaluation. But DSS performance can be very challenging to assess in a number of respects, including temporal challenges related to how DSS is employed at multiple points before (pre-planned) and within the dynamic timeline of a traffic incident or event. Other challenges include differentiating shortcomings of the DSS itself from other factors that may diminish success such as operators unable or unwilling to carry out DSS recommendations.	• The evaluation features an analysis area (and considerable resources) focusing on DSS utilization and performance. Information on operator responses, time to response, and deviation between calculated result and actual result will be captured in the evaluation, either through built-in DSS logging capabilities or supplemental logging. • The evaluation approach elaborated in the test plans will reflect a thorough understanding and articulation of each sites' specific plans for DSS utilization and their DSS capabilities. • Carefully document all of the exogenous factors that can mask or diminish the apparent overall value of DSS, including factors impeding fully implementation of DSS recommendations.
Emphasis on corridor person movement (trips, throughput) in addition to documentation of network conditions (speeds, travel times, etc.)	ICM inherently emphasizes corridor-level and total trip mobility in terms of serving trips (travel demands) as opposed to focusing exclusively on the performance of any specific facility or service.	• The evaluation will document the performance of individual facilities and services using traditional field data. • The evaluation will also utilize traveler surveys and ICM AMS tools (modeling) to capture the corridor-wide, overall trip dimensions of performance.

Table 3-3. ICM Evaluation Challenges and High-Level Evaluation Approaches (Continued)

Challenge	Description	High-level Evaluation Approach
Special (non-continuous, non-automated) data collection during incidents	Phase 3, Stage 2 AMS results indicate that the vast majority of ICM benefits will be realized during incidents or periods of unusually high demand. Given the limited predictability of such conditions, it is challenging to perform any special, manual data collection (e.g., floating car runs or average vehicle occupancy observations) during these crucial periods.	• The evaluation will seek to limit special, manual data collection that would have to be carefully timed to coincide with incidents to the minimum amount required to address important evaluation questions. • In the limited cases where such data collection is necessary, likely time periods will be identified based on the "cluster analysis" conducted during Phase 3, Stage 2 AMS work.
Consideration of scenarios (e.g., typical daily, major incident, minor incident, weather)	The value and specific applications of ICM will vary significantly during various circumstances. ICM is both partly intended to address non-typical conditions, and its effectiveness is influenced by these conditions (e.g., weather) insomuch as these conditions can be exogenous factors. "Average annual daily" indicators are not applicable to ICM evaluation.	• The evaluation will explicitly investigate ICM performance under various conditions and will define those conditions in consideration of the conditions/scenarios utilized in the AMS work. • Statistical modeling techniques as well as surveys will be used to understand the influence of weather and incidents on traveler responses to ICM. • AMS results will be used to inform the understanding of the influence of weather conditions on ICM performance.
Exogenous factors (gas prices, unemployment, non-ICM transportation system changes, changes in ICM systems throughout post-deployment, etc)	As with many ITS/operations technology deployment evaluations, there are a number of exogenous factors that can partially or completely obscure the impact of the deployment and which challenge the ability to attribute observed impacts to the deployment. This challenge is especially great in the case of ICM because AMS Phase 3, Stage 2 analysis indicates a low "signal-to-noise ratio," that is a low ratio of ICM-related changes to changes stemming from exogenous influences.	• Exogenous factors will be carefully tracked and taken into consideration—at the least qualitatively and, when possible, quantitatively. • The AMS results will be taken into consideration in determining the impact of exogenous factors. • Traveler surveys provide an opportunity to differentiate ICM from non-ICM influences on traveler response. • The stepwise investigation of each link in the cause-effect chain implicit to the logic model approach aids the understanding of whether given results are the product of the deployment or exogenous factors. • Data permitting, the evaluation will consider more than just a 12-month period prior to ICM implementation but will also consider available historic data showing longer-term trends and cyclical variations.
Feedback loops ("evolving post-deployment condition")	The post-deployment condition is likely to evolve in at least two respects: 1) Utilization of the ICM elements (operational strategies) will evolve throughout the entire post-deployment period, beyond the 6-month "shakedown period;" and 2) ICM strategy implementation early in the post-deployment period may produce a lasting change in traveler response and/or the performance of specific facilities and services, thus altering the nature and impact of ICM strategy implementation in the later stages of the post-deployment period.	• The evaluation will utilize, to the extent possible, continuous data collection or multiple, recurring data sampling over the entire post-deployment period (e.g., multiple survey waves) to enable both comparison of "pre-" to "post-deployment" as well as investigation of conditions within the post-deployment period. • Non-incident/event conditions (periods when there is limited explicit ICM strategy implementation at play) will be compared at different times within the post-deployment period to aid in the understanding of any lasting changes associated with ICM that might suggest a "re-set" of the baseline conditions.

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3.5 Data Types

The evaluation will utilize a wide variety of data. The major categories of data are summarized in Table 3-4.

Table 3-4. Evaluation Data Types

Data Type	Description	Typical Characteristics
ICM System Data	Data generated by ICM hardware and software components, e.g., system-generated logs of operators' interactions with the DSS and subsequent strategy-execution actions. Critical in documenting how the ICM elements were utilized and how they performed.	• Medium-sized, quantitative data sets • Mostly automated collection and archival (once built into the system design and functionality) but may also include some manual record keeping by ICM deployers
Transportation System Data	Data describing transportation facility and service utilization and performance, e.g., traffic volumes and speeds and transit ridership.	• Medium to large quantitative data sets • Mostly automated collection and archival with a few exceptions, such as floating car data collection for emissions driving schedule (vehicle operating mode) data
Transportation System Operator Perceptions	One-on-one or small group discussions with transportation system operators—including DSS and control room operators—and other key ICM stakeholders such as planners, developers and agency leadership. Also includes first-hand observation of control center activities. Instrumental in understanding how the ICM elements were used and how they performed, as well as gathering institutional/organization analysis data, including lessons learned.	• Smaller-sized, qualitative data sets consisting of notes, transcripts, photos, video and/or audio recordings. • Primarily manual, labor-intensive data collection
Traveler Stated and Observed Preference	Quantitative and qualitative data that informs the understanding of traveler response to the ICM deployments.	• Collected via surveys, travel diaries (with or without in-vehicle instruments), interviews and focus groups • Medium to large-sized data qualitative and quantitative data sets • Primarily resource-intensive manual data collection
AMS Results	Data collected from the Phase 3 AMS tools. Useful in capturing corridor or trip (as opposed to facility/service) performance and person (as opposed to vehicle)-based measures of mobility. Also provides a means to control for exogenous factors such as weather conditions and background (non-ICM related) traffic growth.	• Quantitative data • Requires calibration and application of AMS tools

As shown in Table 3-4, qualitative data on transportation system operator perceptions will play a role in the evaluation. In considering operator perceptions, it is very important to also consider the extent to which the operators can point to evidence that supports their perceptions or to compare those perceptions to other, quantitative data collected through the evaluation. However, even operator perceptions that are not supported by “facts” can also be quite useful in the area of decision support systems where operator trust and confidence in the DSS and its recommendations—whether or not backed up by concrete evidence—plays a critical role in whether and how the operators utilize the tool.

Most of the data types identified in Table 3-4 are quite common to evaluations of ITS/operations field deployments. However, utilization of modeling or simulation in the evaluation of real-world deployments like the ICM Demonstration Phase is less common. The ICM evaluation presents both challenges and opportunities that make utilization of AMS tools important.

One challenge is that ICM is, inherently, focused on maximizing overall corridor performance in terms of person movements rather than on maximizing the performance of individual, modal components of the corridor transportation system—e.g., roads, bus routes and rail lines. Corridor-level, person trip performance is very difficult to assess using field data because those data typically only cover portions of the trip and are fundamentally tied to transportation infrastructure (roads, buses, etc.) rather than to people and trips. Summing up the person throughput across facilities and services is informative—and will be done in this evaluation—but such an approach still focuses on infrastructure performance, albeit on an aggregate corridor level. Such an approach does not provide understanding of the improvements from the traveler’s or trip perspective, which typically entail travel on portions of multiple routes and even modes, including in areas beyond the footprint of facility-based field data collection.

Another challenge concerns differentiating changes stemming from the ICM deployment and those resulting from exogenous factors like weather or background traffic increases or decreases. This challenge is present in nearly all evaluations of field deployments but is an especially significant challenge for this evaluation given the expected low “signal-to-noise ratio.” Phase 3, Stage 2 AMS modeling suggests that aggregate, system-wide ICM benefits may be relatively small and non-uniform and therefore difficult to distinguish from non-ICM related variation in transportation system performance measures.

The AMS tools represent a rare opportunity, though, in that few evaluations have at their disposal modeling or simulation tools that have been extensively customized or calibrated to estimate the impact of the technology deployment that is being evaluated. Specific uses of the AMS tools within the national evaluation are discussed in the analysis approaches presented in Chapter 5 and include the following:

- A source for corridor person trip measures, including throughput and trip travel times.
- A potential source for trip travel times associated with those specific origin-destination pairs and specific travel paths where ICM benefits may be very significant.

- A tool to assist in the estimation of required sample sizes and associated statistical power for traveler surveys (by providing a prediction of the magnitude of ICM-related change and the types of travelers likely to experience it).
- An external validation point for survey findings (survey and AMS results should be similar and if they are not, it will indicate that both the survey and AMS should be further examined).
- Providing results for scenarios that were not reflected in the traveler surveys, providing that the AMS results are sufficiently consistent with the survey results for scenarios that were covered in the surveys.
- A tool for understanding the influence of exogenous factors such as weather and construction on ICM impacts.

The evaluation will take care in utilizing the AMS tools, including considering on a case-by-case basis whether a particular application requires that the AMS tools be calibrated/updated based on other results of the evaluation. For example, it will be important that the person-trip measures are taken from the version of the AMS that has been updated with the key traveler response to information (e.g., what percent access the information and what percent change their behavior because of it) metrics that play such a critical role in the AMS and which will be determined through the evaluation. In other instances, such as using AMS to support survey design (e.g., sample sizes), it is not critical that the model be calibrated/updated.

The evaluation approach to using AMS tools presented in this framework has been vetted with the deployers, U.S. DOT and the AMS contractor and represents a consensus view of what model uses are appropriate and useful. As noted in the various analysis approaches in Chapter 5, final determinations about which desired AMS evaluation applications can be used will be made during test plan development based in part on resource availability.

3.6 Evaluation Timeline and Deployment Phasing Issues

One of the challenges associated with the evaluation of large, multi-faceted ITS/operations field demonstrations is that the different portions of the overall deployment are often implemented and become operational in a phased manner. In theory, this can be useful because it can aid in the understanding of the incremental impact of individual strategies or technologies. In reality, however, this phenomenon poses significant challenges given the overall schedule constraints of the evaluation (start and end times) and the objective of collecting a full year of pre-deployment and post-deployment data.

The phasing of specific ICM strategies/technologies at each site is not yet certain—both sites have schedules (see Section 2.4) showing that the "build" and "unit testing" associated with individual ICM elements will be completed in a phased manner. However, it is not entirely clear whether the elements and associated strategies will be utilized incrementally or what sorts of impacts may result from those incrementally implemented elements. These issues will be investigated with the sites as the test plans are drafted. The discussion here provides insights into how phasing of ICM elements/strategies would, if ultimately pursued by the sites, impact the evaluation.

Figure 3-3 compares an idealized scenario in which all facets of the ICM deployments become operational or "go live" at one point in time versus a scenario in which portions of each site's deployment go live at different points in time spanning a long period. In the latter situation, the problem is that the 12-month period directly leading up to the time when the full ICM system is operational—the period that, ideally, would constitute a good, clean "baseline" (no-ICM) condition—is punctuated by implementation of individual ICM strategies and elements. As such, it would not truly describe a "no-ICM" condition. It is generally agreed among U.S. DOT, the ICM deployers and the evaluation team that the true impact of ICM (which is inherently holistic in its intent and nature) is not manifest until the entire ICM system is working together, at which point the post-deployment period should begin. However, even though implementation of some ICM strategies and elements will not produce the kinds of impacts associated with full implementation, to the extent that those early ICM strategies and elements have <u>some</u> impact, they taint what would ideally be a true baseline condition.

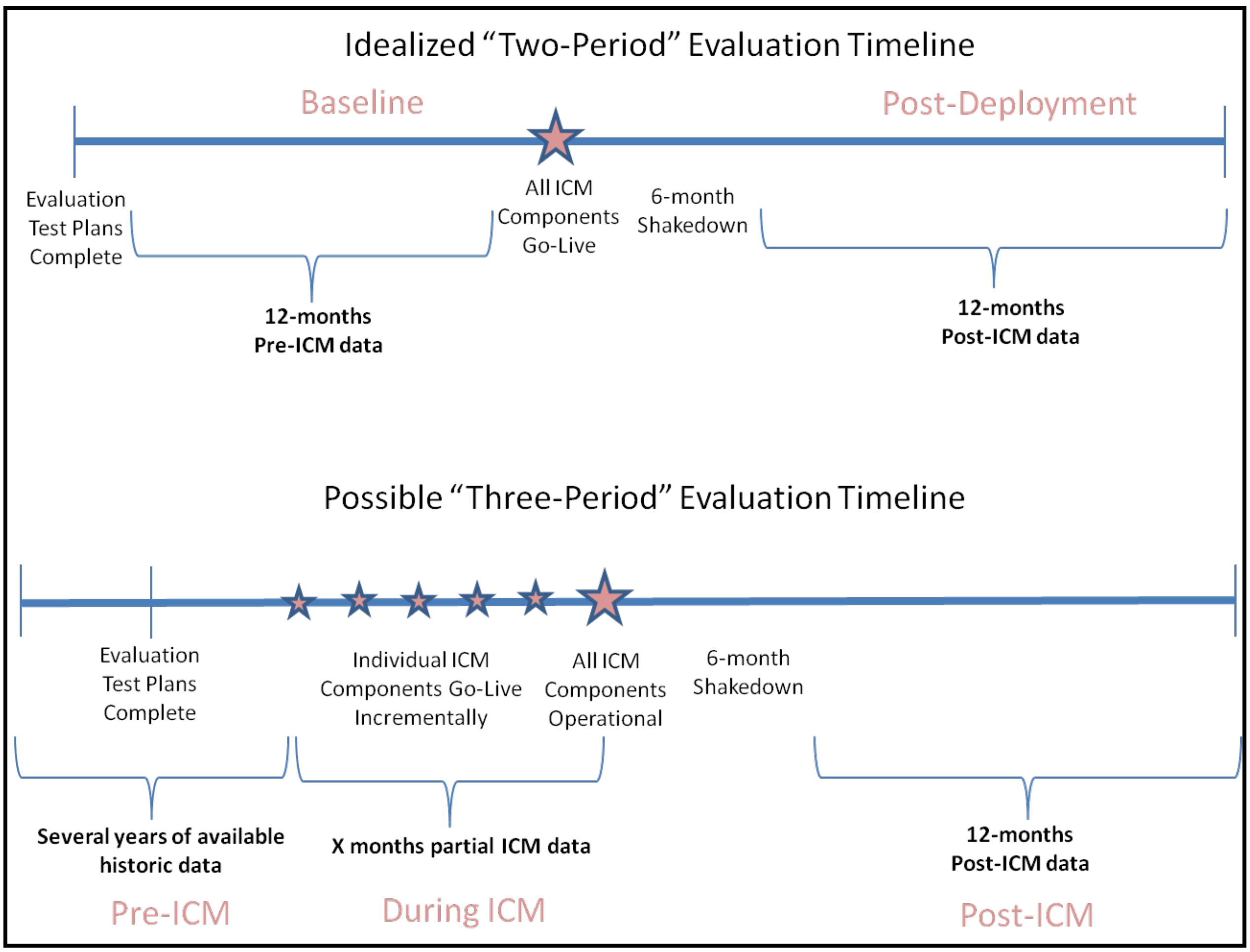

Figure 3-3. Two-Period Versus Three-Period Evaluation Timelines

The ideal solution to this situation (if it proves to exist at either site) would be to start the evaluation far enough in advance so that a full year's worth of data could be collected before any ICM strategies or components become operational. This would, in essence, yield a three-period evaluation timeline: 1) "Baseline" (12 months before any ICM), 2) "During" (after some ICM but before all ICM), and 3) "After" (12 months after the last ICM implementation). Strictly speaking, that is not an option—some of the desired evaluation data is not currently being archived. However, some key evaluation data such as freeway traffic volumes and transit ridership are available going back several years before the first ICM strategy/technology implementation. So, if this three-period evaluation data collection approach is utilized, the first period would rely upon available historic data for the "before any ICM" evaluation time period. Because such data would be at least somewhat incomplete, it would probably not support all evaluation hypothesis testing.

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4.0 APPLYING THE LOGIC MODEL THROUGH EVALUATION ANALYSES

Section 3.2 discussed how the overall analytical approach to the ICM evaluation is based on a "logic model" approach that recognizes the inherent dependency of bottom line ICM impacts ("outcomes") on preceding actions or conditions which are characterized as the ICM investments ("inputs") and how those investments perform and are utilized by transportation operators ("outputs"). Section 3.3 went on to explain that, although <u>driven</u> by the logic model, the evaluation activities are <u>organized</u> into eight analyses. This chapter bridges those two concepts by explaining how the logic model and related concepts have been incorporated into the analyses and the evaluation overall. The discussion sets the stage for the individual analysis discussions that constitute the remainder of this chapter.

This discussion is organized around the following four questions:

1. How do the various analyses address inputs, outputs and outcomes?
2. How do the analyses recognize and address the linkage between what gets deployed and operated with impacts?
3. How do the analyses reflect the inherent cause-effect, tiered relationships among impacts (measures of effectiveness), e.g., a traveler needing to access and value traveler information before changing their behavior because of it?
4. How will the analysis attempt to determine the individual impact of specific ICM strategies, e.g., the marginal contribution of DSS?

4.1 Addressing Inputs, Outputs and Outcomes

A thorough understanding of inputs—the investments made by the deployers, including hardware, software and other infrastructure that was implemented; what training was conducted; what operating policies, procedures and techniques were changed; etc.—is a standard part of any evaluation and provides the foundation for specific hypothesis testing and results reporting. A traditional and key portion of an evaluation results report is an early chapter that clearly documents the inputs and that approach will be taken here. Inputs associated with the ICM deployment will be documented both through the overarching deployment monitoring that occurs over the entire course of the evaluation as well as through data collection occurring within some individual analyses. Specifically, the TECHCAP and DSS Analyses will provide considerable information on inputs because these analyses focus primarily on what gets deployed and the associated capabilities. That is, these analyses focus on outputs, which are directly linked to inputs in the logic model's cause-effect chain. Also, the I&O Analysis will play a key role in the documentation of inputs, both in terms of what was or was not implemented but also how and why.

Outputs and outcomes are reflected in the various evaluation analyses as specific measures of effectiveness. Outputs are concentrated primarily in the TECHCAP and DSS Analyses, as those analyses explicitly consider ICM capabilities and how they are exercised by transportation operators. Conversely, analyses such as Safety and Mobility focus primarily on outcome measures of effectiveness (MOEs) and will rely on the results of the other analyses to understand how and why the observed outcomes came about. Understanding the impact of various ICM strategies and the ICM deployment overall will necessarily, then, involve consideration of results from across the analyses—which is to say, the results along the length of the logic model cause-effect chain.

4.2 Cause-Effect Relationships Among MOEs

Even among MOEs that are all “outputs” or all “outcomes,” that is, among MOEs that are in the same general portion of the logic model or cause-effect chain, there can still be important cause-effect relationships. Where present, these relationships have been reflected in the evaluation analysis discussions by organizing hypotheses and their associated MOEs into categories and presenting those categories in the cause-effect sequence. For example, the Traveler Response Analysis includes only outcome MOEs—it is focused near the overall end of the ICM cause-effect chain; many things must happen upstream (agencies sharing data, agencies disseminating traveler information) before there can be any sort of traveler response. However, within the Traveler Response Analysis area, there is clearly an internal sequence of cause and effect: travelers must first be aware of information; then they must consult, understand, trust and value it; and only then may they change their behavior because of it. This internal sequence has been reflected in the Traveler Response Analysis (Section 5.3) by organizing hypotheses (and their associated MOEs) into the categories of “awareness,” “utilization,” “satisfaction,” etc.

4.3 Linkages Between Deployments and Impacts

The connection between the deployments and various potential impacts is reflected in the analysis-based evaluation approach that is described in Chapter 5 in two ways. First, the individual hypotheses in each analysis (each of which is tied to a specific MOE) conceptually link the ICM deployment with the hypothesized impact. For example, “Improved inter-agency communications and data sharing will result in more timely notification and verification of incidents.” Note, however, that many ICM impacts are the result of the combined influence of the ICM deployment overall and therefore there are hypotheses in the various analyses that cite “the ICM deployment” rather than an individual strategy or set of strategies.

The second way that the linkages between ICM strategies and specific impacts can be traced through the various analyses is via the master trace that has been established between every MOE that appears in the evaluation analyses and all of the ICM strategies. That trace is presented in Table 4-1. The ICM strategies shown in the first column of Table 4-1 are categorized either as “foundational” or “control.” Foundational strategies are those that provide a capability but do not directly implement an action to manipulate transportation supply or demand. For example, a strategy that shares information among agencies enables control strategies (which are specifically named in other analyses) but does not directly implement those actions. Control strategies on the other hand are those that do entail manipulation of supply or demand. Given these distinctions, it is clear that, as shown in Table 4-1, the foundational strategies have only, or mostly, output MOE’s. The evaluation will endeavor to understand the role played by foundational strategies in contributing to outcomes, a process that will include considering results from along the length of the logic model; linking the results from output-oriented analyses with outcome-oriented analyses.

Also note that in order to simplify Table 4-1, not all of the outcomes associated with traveler information strategies have been listed. Rather, only the outcomes through the "traveler behavior change" link in the cause-effect chain have been shown. Clearly, those traveler behavior changes will contribute to changes in "bottom line" transportation system performance (the mobility, safety and air quality impacts that are the downstream links in the chain) but those bottom line outcomes will be influenced by more than just the traveler behavior changes. The evaluation will endeavor to understand the role played by the traveler behavior changes in contributing to the bottom line outcomes.

4.4 Determining Individual Strategy Impacts

One of the goals of the evaluation is to determine, to the extent possible, the marginal contribution of individual ICM strategies. This will be very challenging given that ICM is inherently a synergistic endeavor in which ultimate success depends on a wide range of enabling actions and capabilities. However, the evaluation will employ a number of techniques to attempt to disentangle individual strategy impacts from cumulative effects. These techniques include the following:

- Taking advantage of any "natural experiment" opportunities associated with possible phase-in of ICM strategies/subsystems.
- Use of well-calibrated AMS tools to understand if not the specific, quantitative impact of individual strategies at least the magnitude of the roles played by various strategies on overall results.
- Use of the traveler surveys conducted as part of the Traveler Response Analysis to better understand what aspects of the ICM deployment led to what sorts of traveler responses, or lack thereof.
- Using the pattern of logic model results associated with particular investments to narrow down the possibilities for what caused a specific result. For example, if the inputs and outputs associated with a particular strategy were not successfully accomplished but an outcome was, it could be concluded that the outcome was the result of other strategies. This notion of looking across the length of the logic model (cause-effect sequence) also entails looking across various analyses, e.g., interpretation of the Mobility Analysis results (which are outcome-oriented) will reference the results of the DSS and Monitoring, Control and Report Analysis results (which include many output measures).

Table 4-1. Master Trace of Evaluation MOEs to ICM Strategies

ICM Strategy *(and type, "Foundational" or "Control")*	Direct Outputs	Direct Outcomes
Legend – MCR – Monitor, Control and Report; DSS – Decision Support System; TR – Traveler Response; MOB – Mobility; I&O – Institutional and Organizational; SAF – Safety; AQ – Air Quality; BCA – Benefit-Cost Analysis		
• Manual information sharing *(Foundational)* • Automated information sharing (video real-time data) *(Foundational)* • Information clearinghouse / Information Exchange Network *(Foundational)* • A common incident reporting system *(Foundational)* • Multi-agency/multi-network incident response teams/service patrols and training exercises *(Control)*	MCR - Change in percent of incident notifications received in under X minutes (across modes, routes in the corridor) before and after ICM MCR - Change in incident data feeds available to each individual agency before and after ICM MCR - Change in notification time that an incident has cleared MCR - Change in number of incidents being logged into the ICMS from the various CAD provider (s) MCR - Change in number of agencies using common incident reporting system MCR - Change in incident response and clearance time MCR - Change in time required to implement proposed response strategies and dispose system resources for the corridor MCR - Change in number of agencies alerted to incidents via roadside call boxes ----- MCR - Change in percent of peak periods with the availability of multi-modal comparative travel times. MCR - Change in number of agencies sharing video feeds pre- and post-ICM MCR - Change in number of transit (bus, BRT, LRT) routes in corridor providing real-time information to ICMS (vehicle locations, capacity, schedule adherence) MCR - Change in percentage of centerline miles of real-time arterial information in the ICMS MCR - Change in availability of real-time parking lot utilization information in the ICMS ---- MCR - Change in perceptions of improved capability to monitor and report effectively on the system resources in the corridor MCR - Change in perceived improvements in system data quality to assist operators in making decisions MCR - Change in perceived usefulness of predicted and real-time information provided to operators for interpretation and decision making MCR - Change in level of satisfaction with inter-organizational coordination measures based on operator feedback MCR - Change in perceived effectiveness of coordinated incident response plans implemented	MOB - Change in Incident-Related Travel Time by Mode and for Corridor-wide MOB - Change in Incident-Related Delay by Mode and for Corridor-wide MOB - Changes in Incident-Related Throughput by Mode and for Corridor-wide *(No other "direct" outcomes – these largely "foundational" strategies will contribute indirectly to outcomes which are listed elsewhere in this table with the "control" strategies which directly produce them.)*

Table 4-1. Master Trace of Evaluation MOEs to ICM Strategies (Continued)

ICM Strategy *(and type, "Foundational" or "Control")*	Direct Outputs	Direct Outcomes
Legend – MCR – Monitor, Control and Report; DSS – Decision Support System; TR – Traveler Response; MOB – Mobility; I&O – Institutional and Organizational; SAF – Safety; AQ – Air Quality; BCA – Benefit-Cost Analysis		
• Use of DSS to support corridor management *(Foundational)*	MCR - Change in percentage of DSS suggestions/ responses consistent with operators' experience and expectations MCR - Level of operator intervention in altering recommended responses MCR - Perceived performance of DSS predictive capabilities MCR - Change in number of instances the TMC has requested additional resources from corridor stakeholders based on DSS recommendations DSS - Successful rate of data fusion engine in taking data from disparate sources DSS - Successful rate of data fusion engine in standardizing data DSS - Successful rate of data fusion engine in recognizing overlaps in data DSS - Successful rate of data fusion engine in recognizing gaps in data DSS - Perceived quality of responses, including improvement relative to any comparable pre-ICM approaches DSS - Percentage of responses consistent with operators' experience and expectations DSS - Percentage of times operator implements recommended responses DSS - Percentage of times operator alters recommended responses DSS - Perceived usefulness of information provided to Operators for interpretation and decision making DSS - Level of operator intervention in altering recommended responses DSS - Difference between predicted outcomes and actual operation conditions in terms of corridor performance (volumes, speeds, travel times, and throughput) in various scenarios DSS - Perceived accuracy of predictions DSS - Average time for DSS to deliver an actionable response plan DSS - Average time for DSS to deliver predictions of strategy outcomes DSS - Perceived level of human intervention required during the DSS' development of an actionable response plan	*(No "direct" outcomes – this "foundational" strategy will contribute indirectly to outcomes which are listed elsewhere in this table with the "control" strategies which directly produce them.)*

Table 4-1. Master Trace of Evaluation MOEs to ICM Strategies (Continued)

ICM Strategy *(and type, "Foundational" or "Control")*	Direct Outputs	Direct Outcomes
Legend – MCR – Monitor, Control and Report; DSS – Decision Support System; TR – Traveler Response; MOB – Mobility; I&O – Institutional and Organizational; SAF – Safety; AQ – Air Quality; BCA – Benefit-Cost Analysis		
• Information clearinghouse / Information Exchange Network *(Foundational)* • Pre-Trip Traveler Information *(Control)* • En-Route Traveler Information *(Control)* • Transit Traveler Information *(Control)* • Access to corridor ATIS database by 3rd party information providers *(Foundational)*	MCR - Change in time to notification of incidents, other capacity reductions, other disruptions and return to normal operations to ATIS (including 3rd Party ISPs, Media, agency websites and 511) MCR - Changes in the nature and the number of unique DMS messages executed in response to incidents and other conditions in the corridor MCR - Changes in the nature and number of pre-trip traveler information dissemination (511, Websites) MCR - Change in number of ISPs accessing corridor information from integrated database MCR - Change in number of media updates made for distribution to the traveling public MCR - Change in operator's perceived usefulness and improvements in information provided to travelers	TR- All the strategy outcome MOEs relating to traveler response and behavior will be added once the Traveler Response Analysis is completed (see placeholder in Section 5.3)
• Promote route shifts between roadways and transit via en-route traveler information devices *(Control)* • Promote shifts between transit facilities via en-route traveler information devices (e.g., by comparing travel times) *(Control)* • Planned temporary addition of transit capacity/signal priority for extra transit vehicle *(Control)* • Add capacity at parking lots (temporary lots) *(Control)*	MCR - Change in number and nature of instances of diversion information on DMS, HAR, 511, and other ATIS MCR - Change in number and nature of instances when temporary (real-time) transit capacity was added MCR - Change in time from notification to increased transit capacity MCR - Change in number and duration of instances when HOV and lane restrictions were altered MCR - Change in number and nature of instances with temporary parking lot capacity additions MCR - Change in frequency of active transit signal priority calls	TR- All the strategy outcome MOEs relating to traveler response and behavior will be added once the Traveler Response Analysis is completed (see placeholder in Section 5.3) MOB - Changes in Transit Ridership MOB - Changes in Transit Throughput MOB - Changes in Transit On-Time Performance
• Lane use control (configurable lanes/contra-flow) *(Control)* • Modify HOV restrictions (increase minimum number, make bus only) *(Control)*	MCR - Change in number and duration of instances when HOV and lane restrictions were altered	MOB - Changes in Freeway GP Lanes Travel Time MOB - Changes in HOV Lane Travel Time MOB - Changes in Total Vehicle Delay by Mode MOB - Changes in Total Person Delay by Mode MOB - Changes in Total Vehicle Delay – Freeway GP Lanes MOB - Changes in Total Person Delay – Freeway GP Lanes MOB - Changes in Total Vehicle Delay – HOV Lanes MOB - Changes in Total Person Delay – HOV Lanes MOB - Changes in Vehicle Throughput – Corridor and by Mode MOB - Changes in Person Throughput – Corridor and by Mode MOB - Changes in Vehicle Throughput – freeway GP Lanes MOB - Changes in Person Throughput – freeway GP Lanes MOB - Changes in Vehicle Throughput – HOV Lanes MOB - Changes in Person Throughput – HOV Lanes

Table 4-1. Master Trace of Evaluation MOEs to ICM Strategies (Continued)

ICM Strategy *(and type, "Foundational" or "Control")*	Direct Outputs	Direct Outcomes
Legend – MCR – Monitor, Control and Report TR – Traveler Response I&O – Institutional and Organizational AQ – Air Quality DSS – Decision Support System MOB – Mobility SAF – Safety BCA – Benefit-Cost Analysis		
• Modify arterial signal timing plans to accommodate traffic shifting from freeways *(Control)*	MCR - Change in number of instances of changing coordinated timing plans on arterial network for increasing throughput within the corridor during incidents	MOB - Changes in Vehicle Throughput by Mode MOB - Changes in Person Throughput by Mode MOB - Changes in Total Vehicle Delay by Mode MOB - Changes in Total Person Delay by Mode MOB - Changes in Average Person Travel Times by Mode
• Modify ramp metering rates to accommodate traffic (including buses) shifting from arterials *(Control)* • Coordination of ramp and traffic signals in vicinity *(Control)*	MCR - Change in the number of instances when ramp metering rates were changed based on ICM strategies MCR - Change in the time required to modify ramp metering rates	MOB - Changes in Vehicle Throughput by Mode MOB - Changes in Person Throughput by Mode MOB - Changes in Total Vehicle Delay by Mode MOB - Changes in Total Person Delay by Mode MOB - Changes in Average Travel Times by Mode
• Coordinate scheduled maintenance and construction activities among corridor networks *(Control)*	MCR - Change in perceived improvement in schedule coordination of maintenance and construction activities MCR - Number of construction/maintenance events shifted as a result of shared construction and maintenance information across agencies	*(No "direct" outcomes – this "foundational" strategy will contribute indirectly to outcomes which are listed elsewhere in this table with the "control" strategies which directly produce them.)*

Table 4-1. Master Trace of Evaluation MOEs to ICM Strategies (Continued)

ICM Strategy *(and type, "Foundational" or "Control")*	Direct Outputs	Direct Outcomes
Legend – MCR – Monitor, Control and Report; DSS – Decision Support System; TR – Traveler Response; MOB – Mobility; I&O – Institutional and Organizational; SAF – Safety; AQ – Air Quality; BCA – Benefit-Cost Analysis		
• Overall ICM deployment (all strategies in concert)		MOB - Changes in Freeway GP Lanes Travel Time MOB - Changes in HOV Lane Travel Time MOB - Changes in Frontage Road and Arterial Travel Times MOB - Changes in Transit Travel Time MOB - Changes in Average Person Travel Time by Mode MOB - Change in Incident-Related Travel Time by Mode MOB - Changes in Total Vehicle Delay by Mode MOB - Changes in Total Person Delay by Mode MOB - Changes in Total Vehicle Delay – Freeway GP Lanes MOB - Changes in Total Person Delay – Freeway GP Lanes MOB - Changes in Total Vehicle Delay – HOV Lanes MOB - Changes in Total Person Delay – HOV Lanes MOB - Changes in Total Vehicle Delay – Arterials/Frontage Roads MOB - Changes in Total Person Delay – Arterials/Frontage Roads MOB - Changes in Delay per vehicle by mode MOB - Changes in Total Transit Passenger Delay MOB - Change in Incident-Related Delay by Mode MOB - Changes in Transit ridership MOB - Changes in Vehicle Throughput – Corridor and by Mode MOB - Changes in Person Throughput – Corridor and by Mode MOB - Changes in Vehicle Throughput – freeway GP Lanes MOB - Changes in Person Throughput – freeway GP Lanes MOB - Changes in Vehicle Throughput – HOV Lanes MOB - Changes in Person Throughput – HOV Lanes MOB - Changes in Vehicle Throughput – Arterials/Frontage Roads MOB - Changes in Person Throughput – Arterials/Frontage Roads MOB - Changes in Transit Throughput MOB - Changes in Vehicle-miles traveled by mode MOB - Changes in Person-miles traveled by mode MOB - Changes in Vehicle hours traveled by mode MOB - Changes in Person hours traveled by mode MOB - Changes in Incident-Related Throughput by Mode MOB - Changes in Travel Time Index by Mode MOB - Changes in 95th percentile travel time by Mode MOB - Changes in Standard deviation of travel time by Mode MOB - Changes in Planning time index by Mode MOB - Changes in Buffer index by Mode MOB - Changes in Transit On-Time Performance

Table 4-1. Master Trace of Evaluation MOEs to ICM Strategies (Continued)

ICM Strategy *(and type, "Foundational" or "Control")*	Direct Outputs	Direct Outcomes
Legend – MCR – Monitor, Control and Report; DSS – Decision Support System; TR – Traveler Response; MOB – Mobility; I&O – Institutional and Organizational; SAF – Safety; AQ – Air Quality; BCA – Benefit-Cost Analysis		
• Overall ICM deployment (all strategies in concert)	I&O- Change in the number and level of new agreements in the region I&O- Percentage of "total" and "active" agencies participating in ICM I&O- Changes in perceptions of deployment agencies on efficacy and satisfaction of arrangements I&O- Changes in perceptions of USDOT on the efficacy and satisfaction of arrangements I&O- Changes in decision-making roles and responsibilities I&O- Change in number of communications between transportation partners I&O- Perceptions of level of comfort in the capacity to use ICM during complex situations I&O- Perceptions and comfort level with inter-agency device control and sharing I&O- Reduction in the Percentage of time spent on routine issues I&O- Changes in conflict identification, logging, and resolution approaches I&O- Development of a regionally agreed upon shared vision I&O- Changes in organization and institutional structures I&O- Number of predefined strategies for coordinated action I&O- Changes in the situational awareness capabilities of partner agencies I&O- Changes in agency perceptions of the ICM over the demonstration phase I&O- Level of agency acceptance and use of ICMS I&O- Reliability and value assessment of ICMS and other tools I&O- Diversity and stability of funding beyond the demonstration phase for ICM I&O- Incorporation of organizational structures and personnel requirements into agency budgets I&O- Changes in O&M Practices to focus on corridor-critical resources I&O- Changes in performance assessment approaches reported by partner agencies I&O- Increase in the number and nature of communications between transportation partners for daily operations I&O- Incorporation of lessons learned into knowledge and tech transfer activities	

Table 4-1. Master Trace of Evaluation MOEs to ICM Strategies (Continued)

ICM Strategy *(and type, "Foundational" or "Control")*	Direct Outputs	Direct Outcomes
Legend – MCR – Monitor, Control and Report; DSS – Decision Support System; TR – Traveler Response; MOB – Mobility; I&O – Institutional and Organizational; SAF – Safety; AQ – Air Quality; BCA – Benefit-Cost Analysis		
• Overall ICM deployment (all strategies in concert)		SAF - Reduction in number of injuries/close calls for first responders (e.g. less exposure to secondary incidents) SAF - Change in the number of secondary crashes/accidents/incidents SAF - Change in the number of crashes/incidents SAF - Change in the geographic clustering of incidents/accidents. SAF - Change in the severity of accidents (rating) SAF - Change in the percent of responders citing improvements in safety SAF - Change in the percent of travelers citing improvements in safety ---- AQ- Reductions in emissions due to VMT reductions AQ- Reductions in emissions due to vehicle population reductions AQ- Reductions in emissions due to decreased congestions (and associated speed profile changes) AQ- --- BCA - ICM will generate present value benefits that exceed costs

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5.0 APPROACH TO EVALUATION ANALYSES

This chapter presents the high-level approaches to each of the eight evaluation analyses that have been identified to date. If necessary, additional analyses will be added as test plans are developed to accommodate any site-specific evaluation issues that may yet surface which do not fit logically into one of these eight analyses.

The general evaluation approaches presented in this chapter apply to both sites; any site-specific differences in terms of ICM approaches (of which there are, overall, relatively few) are manifested in the data source portions of the data tables. Site specific refinement of the approaches presented in this framework will be made in the development of the site-specific evaluation test plans. For example, the word “operator” in some MOEs will be refined to “ICM Coordinator” in the case of Dallas. Also, during test plan development certain MOEs may be disaggregated into two or more separate MOEs or some MOEs may be aggregated. The detailed test plans will also reflect some expected differences in the finer points of each site’s strategies and systems. For example, it is expected that for Dallas the ICM Coordinator may do little if any real-time revision of DSS-recommended response plans and so the associated MOE will be fine tuned and site-specific expectations elaborated.

It was noted in Section 2.3.1 that the various Dallas and San Diego ICMS capabilities and strategies are expected to be utilized within different contexts and timeframes, including real-time unplanned, pre-planned and periodic in response to evolving conditions, traveler responses or cyclical/seasonal changes in demand. At this framework level, individual MOEs have not been disaggregated into those pertaining to the various contexts and timeframes, but the approaches presented here do assume data collection and analysis for any and all ICM system utilization, across all contexts and timeframes. For example, when interviewing operators about their uses of the ICM system the evaluation team will specifically probe for all uses—real time, in advance for planned events and in advance periodic adjustments. During test plan development MOEs, data collection and data analysis methods will be further elaborated if necessary to explicitly address ICM utilization and impacts during the various context and timeframes.

Each of the analyses presented in the sections that follow begin with an overview of the analysis followed by discussions of hypotheses; MOEs, data and data sources; analysis approach; and issues. The analysis approach sections discuss key issues pertaining to data collection and data analysis, the basic analysis design (e.g., case study or system impacts evaluation), and exogenous factors. The issues discussion recaps major challenges and highlights any topics requiring particular attention during test plan development. Note that the exogenous factor discussions within each analysis approach focus primarily on exogenous factors directly linked to the particular analyses. The site-specific test plans that will be developed will include a comprehensive list of exogenous factors, including changes in transportation infrastructure, policies or procedures such as HOV requirement or HOT lane prices, changes in transit service or fares, etc. If any of these changes are found to be related to the ICM deployment, they will be considered as an impact rather than an exogenous factor.

Battelle has designated analysis leaders who will oversee and coordinate all activities within his respective analysis. Each leader will serve as the main point of contact for each site's deployment team for the specific analysis. In the limited cases where there are common data types or data collection methods referenced in more than one evaluation analysis—such as interviews with ICM site stakeholders of various types—the evaluation leaders will coordinate their activities to simplify their interactions with the deployers. Each analysis leader will be responsible for collecting, ensuring the quality, and analyzing all of the data associated with their analysis. Approaches for data checking and quality control will be identified in the site-specific test plans and will likely include a combination of responsibilities on the part of the data providers (e.g., the sites performing certain checks before transmitting) and on the part of the analysis leaders as they receive the data.

5.1 Technical Capability Analysis

The ability of each ICM site to integrate systems and resources, monitor the conditions and capacity of the corridor, implement management strategies, control ITS devices and resources, and report on the status of the corridor in an integrated and cooperative manner is critical to the effectiveness and success of the ICM system. The Technical Capability analysis will thoroughly investigate and document these foundational capabilities, comparing conditions pre- and post-ICM deployment. The following three areas of capability will be assessed:

1. **Monitoring the conditions and capacity of the corridor** – System monitoring capability is a necessity for making effective operational and response decisions, including those pertaining to high-demand (congestion) and incidents. This includes the capability of monitoring the **resources** that have been utilized/deployed in addition to monitoring the corridor capacity and conditions. For example, the evaluation team will assess sites' abilities to monitor the transit service performance such as headways, schedule adherence, and utilization (passenger counts). Another example would be the monitoring of the signal operations by addressing whether the signal is doing what it was intended to and whether the corridor conditions are improving as a result.
2. **Controlling the ITS devices and resources that have a direct impact on the corridor** – The sites' ability to control their devices and resources is key to successful implementation of ICM strategies to effectively manage traffic, respond to incidents, and mitigate congestion.
3. **Reporting on the status of the corridor** – These capabilities allow transportation operators to provide accurate information to personnel responsible for carrying out control strategies (modifying signal timing plans, changing configurable lane use designations, etc.) and to provide travelers with information to support behavior changes that contribute to load balancing.

Three categories of evaluation hypotheses correspond to these three areas of Technical Capability. This analysis will use quantitative and qualitative information, including system data, transportation operator surveys and interviews and on-site observation. Key challenges in this analysis include the need for careful questionnaire design to maximize the value of interview and survey data, timing of on-site observations, and the need to preserve data on operators' use of the ICM-enabled capabilities either by building the logging functions into the systems or by some form of supplemental operator record keeping.

The Technical Capability analysis includes several hypotheses and MOEs related to DSS. DSS-related investigations have been divided between this analysis and the DSS Analysis as follows: this analysis considers how the DSS contributes to operator situational awareness and ability to take appropriate actions ("control") whereas the DSS Analysis focuses on operation and performance of the DSS itself, including its speed and predictive accuracy.

Figure 5-1 provides a summary of this analysis area and provides context for the rest of this section linking hypotheses, data sources, design, and analysis approach.

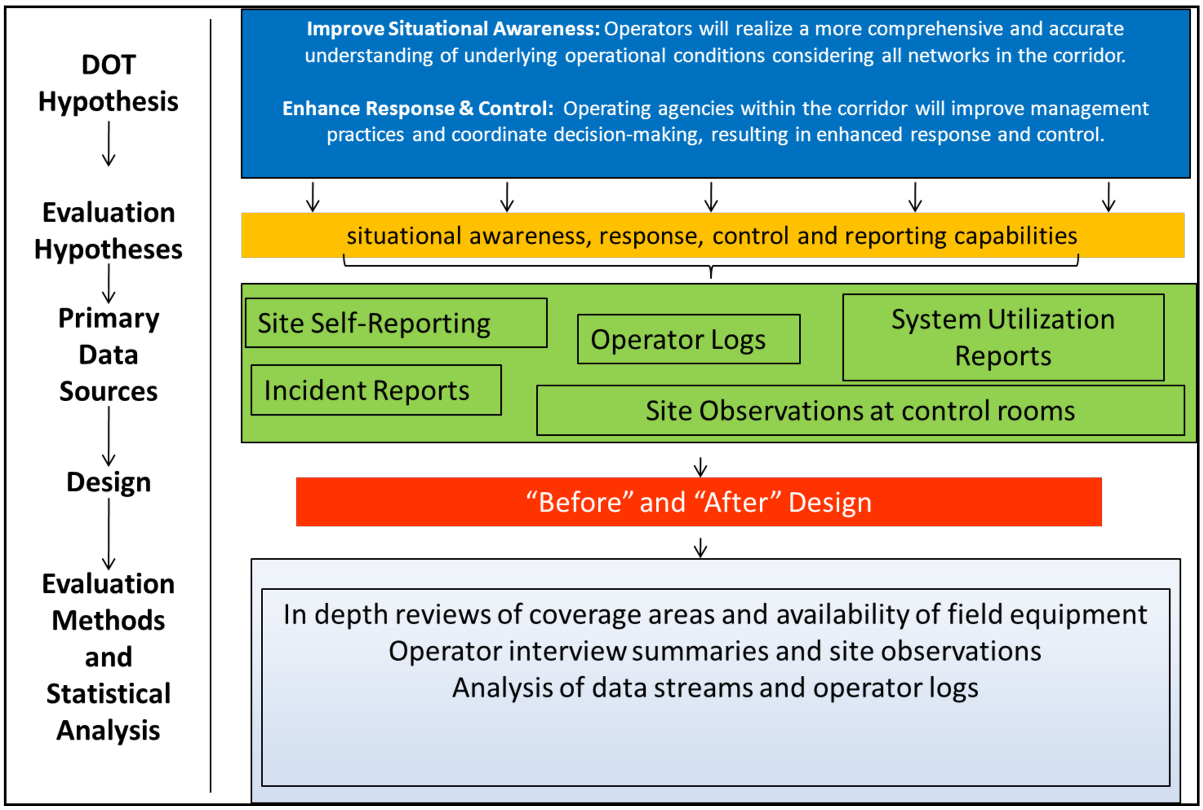

Figure 5-1. Overview of Technical Capability Analysis

5.1.1 Evaluation Hypotheses

U.S. DOT has identified two hypotheses for assessing the improvement in transportation operators' technical capabilities:

- Improve situational awareness, meaning the operators will have a better understanding of the underlying operational conditions and be able to provide better multimodal travel information to the public.
- Enhance the response and control within the corridor through the improved management procedures and coordinated decision making that will need to take place as a result.

This analysis has disaggregated these high-level hypotheses into a series of more discrete, measurable hypotheses that can be individually tested and examined. The evaluation hypotheses are grouped into three areas corresponding to the three areas of capability which are the focus of this analysis: situational awareness (monitoring), control, and reporting. The sequence of these three categories of hypotheses reflect the internal cause-effect (logic model) flow in which improved situational awareness then enables improved control and reporting.

5.1.2 Key MOEs and Data

Each evaluation hypothesis has been linked to one or more key MOEs and the sources for the data needed to develop the MOEs. This information, presented in Table 5-1, is based on preliminary conversations with the deployers at both sites and with U.S. DOT. As the sites' ICM system designs progress and as the development of evaluation test plans begin, this information will be refined, including any site-specific modifications.

Table 5-1. Technical Capability Hypotheses, MOEs, Data and Sources

Hypothesis Area	Evaluation Hypotheses	MOE	Unit	Data	Preferred Data Source
Situational Awareness (Monitor)	Improved data sharing (both real-time data and video) will provide operators with better understanding of mobility conditions in the corridor	Change in percent of peak periods with the availability of multi-modal comparative travel times.	Percentage	Availability and access to comparative travel times on arterials, freeways and transit.	ICMS
	Operators will realize a better and continuous understanding of available system resources and conditions through ICM	Change in number of agencies sharing video feeds pre- and post-ICM	Number	Agencies with access to real-time video data	Interviews/Surveys
		Change in number of transit (bus, BRT, LRT) routes in corridor providing real-time information to ICMS (vehicle locations, capacity, schedule adherence)	Number	Transit System Data	Interviews/Surveys
		Change in percentage of centerline miles of real-time arterial information in the ICMS	Percentage	Arterials data availability	Interviews/Surveys
		Change in availability of real-time parking lot utilization information in the ICMS	Number	Number of parking lots with real-time information	Interviews/Surveys
	Data from the ICMS system will be perceived as high-quality and actionable by the system operators	Change in perceptions of improved capability to monitor and report effectively on the system resources in the corridor	None (qualitative)	Perceptions of operators	Interviews/Surveys
		Change in perceived improvements in system data quality to assist operators in making decisions	None (qualitative)	Perceptions of agency staff (supervisors)	Interviews/Surveys
		Change in percentage of DSS suggestions/ responses consistent with operators' experience and expectations	Percentage	Perceptions of operators	Log
		Change in perceived usefulness of predicted and real-time information provided to operators for interpretation and decision making	None (qualitative)	Perceptions of operators	Log
		Change in Operator's perceived usefulness and improvements in information provided to travelers.	None (qualitative)	Perceptions of operators and agency staff	Log
		Change in perceived incident identification time and prioritization of emerging problems in the corridor.	None (qualitative)	Perceptions of operators and agency staff	Interviews/Surveys
		Level of operator intervention in altering recommended responses	None (qualitative)	Perceptions of operators	Log

Table 5-1. Technical Capability Hypotheses, MOEs, Data and Sources (Continued)

Hypothesis Area	Evaluation Hypotheses	MOE	Unit	Data	Preferred Data Source
Control	Improved intra-agency communications and data sharing will result in more timely notification and validation of incidents in the corridor	Change in percent of incident notifications received in under X minutes (across modes, routes in the corridor) before and after ICM	Percentage	Incident Notification Times (time from first report of incident to the information being available on the ICMS system to corridor stakeholders)	ICMS
		Change in incident data feeds available to each individual agency before and after ICM	Percentage	Agencies with access to CAD and other incident-related data feeds	Interviews/Surveys
		Change in number of incidents being logged into the ICMS from CAD provider (s)	Number	Incident Records	ICMS
		Change in notification time that an incident has cleared.	Percentage	Incident clearance times (time from first report of incident to the notification being given that the incident has cleared)	ICMS
		Change in number of agencies using common incident reporting system	Number	Agencies using common incident reporting system	Log
	Improved intra-agency communications and data sharing will result in quicker response and clearance time for incidents	Change in incident response and clearance time	Minutes	Incident clearance and response times	ICMS
		Change in level of satisfaction with inter-organizational coordination measures based on operator feedback	None (qualitative)	Satisfaction levels	Interviews/Surveys
		Change in number of instances of changing coordinated timing plans on arterial network for increasing throughput within the corridor during incidents	Number	Instances of coordinated timing plan changes	ICMS
		Change in perceived effectiveness of coordinated incident response plans implemented	None (qualitative)	Perceptions of operators	Interviews/Surveys
		Change in time required to implement proposed response strategies and dispose system resources for the corridor	Minutes	Time to implement response plans	ICMS
		Change in number of agencies alerted to incidents via roadside call boxes	Number	Number of agencies alerted to incidents via roadside call-boxes	Interviews/Surveys

Table 5-1. Technical Capability Hypotheses, MOEs, Data and Sources (Continued)

Hypothesis Area	Evaluation Hypotheses	MOE	Unit	Data	Preferred Data Source
Control (Cont.)	DSS will allow for a predictive view of the corridor to fine-tune responses and allow TMCs to proactively respond to corridor conditions	Perceived performance of DSS predictive capabilities	None (qualitative)	Perceptions of operators	Interviews/Surveys
	Improved sharing of construction and maintenance scheduling information among agencies will reduce the number of instances of simultaneous projects on roads which serve as alternate routes to one another	Change in perceived improvement in schedule coordination of maintenance and construction activities	None (qualitative)	Perceptions of operators	Interviews/Surveys
		Number of construction/maintenance events shifted as a result of shared construction and maintenance information among agencies.	Number	Number of instances	Log
	Improved understanding of conditions and improved response plans will allow operators to more effectively modify ramp metering rates as part of ICM strategies	Change in the number of instances when ramp metering rates were changed based on ICM strategies	Number	Number of instances	ICMS
		Change in the time required to modify ramp metering rates	Minutes or seconds	Time required to executive ICM-related changes in timing plans	ICMS

Table 5-1. Technical Capability Hypotheses, MOEs, Data and Sources (Continued)

Hypothesis Area	Evaluation Hypotheses	MOE	Unit	Data	Preferred Data Source
Control & Report	ICM will improve operator's ability to facilitate cross-network and modal shifts	Change in number and nature of instances of diversion information on DMS, HAR, 511, and other ATIS	Number, Descriptive	Number and nature of diversion messages	ICMS
		Change in number and nature of instances when temporary (real-time) transit capacity was added	Number, Descriptive	Number and information about transit capacity addition	ICMS
		Change in time from notification to increased transit capacity	Minutes	Time to notification to increased transit capacity	ICMS
		Change in number and duration of instances when HOV and lane restrictions were altered	Minutes, Number	Number and nature of HOV restrictions	ICMS
		Change in number and nature of instances with temporary parking lot capacity additions	Number, Descriptive	Number and nature of temporary parking lot capacity additions	ICMS
		Change in number of instances the TMC has requested additional resources from corridor stakeholders based on DSS recommendations	Number, Descriptive	Number of instances the TMC has requested additional resources from corridor stakeholders based on DSS recommendations	ICMS
		Change in frequency of active transit signal priority calls	Number	Frequency of active transit signal priority calls (calls per hour)	ICMS
Report	Post ICM, agencies will be able to report corridor conditions in a more timely and actionable manner to travelers	Change in time to notification of incidents, other capacity reductions, disruptions, and return to normal conditions to ATIS (including 3rd Party ISPs, Media, agency websites and 511)	Minutes	Time to notification (elapsed time between control room confirmation of incident and their reporting of it to travelers via ATIS)	ICMS
		Changes in the nature and the number of unique DMS messages executed in response to incidents and other conditions in the corridor	Number and Content	Number and nature of DMS messages	ICMS
		Changes in the nature and number of pre-trip traveler information dissemination (511, Websites)	Number and Content	Number and nature of DMS messages	ICMS
		Change in number of ISPs accessing corridor information from integrated database	Number	ISPs using data in the region	Interviews/Surveys
		Change in number of media updates made for distribution to the traveling public	Number Per day or Per Week	Media updates	Log

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All of the MOEs for this analysis are "outputs" in the logic model discussed in Section 3.2, consistent with the definition of this analysis as being about improvements in "technical capability." The outcomes to which these capabilities contribute will be assessed in the analyses that focus on outcomes (traveler response, mobility, etc.) and the linkage between these capability and the outcomes will be examined drawing on results from all of the analyses.

The Evaluation Team will work closely with the demonstration sites to identify the data and resources that are available and needed for this analysis. Data sources that are essential for this analysis include, but are not limited to:

- ICM System Data: Data generated by ICM hardware and software components. Several types of data needed for this analysis will likely be provided by the ICM System, including:
    - Advanced Traffic Management System (ATMS) data. This includes: (1) numbers and locations of various transportation management systems (e.g., freeway and arterial traffic management centers) and devices (e.g., sensors, detectors, cameras, DMS, traffic signals) that have the capability to monitor, control and report corridor status; (2) technical and functional capabilities (including coverage areas) of each device and system; (3) control and response strategies, such as traffic management plans, signal timing plans, incident response plans, etc.; and (4) hardware, software and system performance reports.
    - Advanced Traveler Information System (ATIS) data. This includes: (1) numbers and types of channels or mechanism for information dissemination; (2) types of information disseminated; and (3) level of details in disseminated information.
    - Incident reports and event records. These include records and reports on incidents, special events, maintenance and construction activities, and response strategies and actions executed for various conditions and events.
    - Shared and exchanged data. This include the types and amount of data shared and exchanged by the ICM partners, include the number of partners providing data to the ICM System and connected to the system for receiving data and alerts.
- Operator/Event/Response Logs: Logs that document agency staff's and system operators' actions on implementing control strategies and their impression of the ICM System.
- Staff/Operator Interviews: Interviews, surveys, and/or discussion groups with agency management and system operators to gather their impression of changes in pre- and post-ICM operations.
- Control Room Observations: Observations of control room activities within the corridor prior to and after ICM deployment, especially during high-complexity situations.

5.1.3 Analysis Approach

This section discusses the basic design of the analysis in terms of the comparisons to be made, scenarios that will be considered, approach to hypotheses testing, and approach to exogenous factors.

The basic design for the analysis is a before-after comparison, including elements of both a case study and an impacts analysis. The case study component is reflected in the key role that qualitative data, including interviews, and control room observations, will play and the examination of specific scenarios or events. The impacts analysis component is reflected more in the quantitative assessment of improvements in the quantity of information and the number of specific types of control and reporting actions taken by operators.

Based on the AMS modeling analysis, the impacts of ICM on corridor operations are predominantly observed during high-demand and incident conditions. To systematically analyze and interpret the effect of ICM on the demonstrations sites' capability to monitor, control and report on the status of the corridor, special attention will be given to both daily recurring congestion periods as well as special scenarios such as:

- Severe weather
- Major traffic incidents
- Major construction/maintenance
- Holidays (both local and national)
- Incidents involving the Department of Homeland Security (e.g., terrorist event, visiting government official on the corridor, etc.)
- Major events (e.g., concerts, community festivities)

It should be understood that ICM tactics can only be carried out, and effective, when there are slack resources available to adjust or allocate to a response plan. In the event that multiple traffic impacting scenarios are taking place (e.g., major sporting event or severe weather), a prioritization of resources will need to be incorporated that could impact the capability of executing all of the recommended ICM response plan components. It is also important to point out that in times of very excessive demand or severe regional events (e.g., regional evacuations due to major nature disasters), triage takes place and there is very little that the ICM can do in response.

This analysis will evaluate the change in the overall "data footprint" in the corridor pre and post-ICM during scenario based events. The assessment will compare the availability of systems and devices to different partner agencies to monitor corridor conditions and to execution of management strategies during pre- and post-ICM deployment periods. In addition, raw system data and system generated reports from the ATMS, ATIS, transit systems, police CAD, 511 systems, and the DSS will be used to verify and evaluate MOEs listed in the previous table. System operator logs or event logs kept by operators or tracked in the ICMS are critical to this analysis to assess improvements in the ability to respond to ongoing and predicted conditions on the corridor. The evaluation team assumes the sites will train and require their staff, particularly system operators, to document their actions in implementing control strategies both in baseline and post-deployment conditions.

In addition to quantitative evaluation, the evaluation team will gather operator opinions and agency staff's perceptions of the effectiveness and reliability of the ICM System using a combination of:

- On-site, pre- and post-deployment control room observations. Observations of system operators in the control room(s) in responding to real-time incidents and congestion, via appropriate response plans, will be valuable information for evaluating operators' perception of the ICM System. The evaluation team will coordinate with the ICM sites to schedule control room observations. Such observations will be conducted once during pre-deployment and again during post-deployment. The evaluation team will work with the sites to determine the best time and durations for the visits based on historical incident data and sites' recommendations.
- Interviews/surveys/discussion groups with system operators and their management. One way to evaluate whether ICM has had an impact on the corridor's operations is to interview system operators to gather their impressions of the system. These impressions, along with system operator logs and on-site observation, will serve as valuable references for not only the system's impact but also for ICM tactics that need to be adjusted in order to improve it.

The following exogenous factors may have impact on this analysis:

- Unrelated software/system upgrades over the course of the analysis could have an impact on data availability. The potential of this happening will need to be investigated prior to starting any analysis activity, allowing the evaluation team to assess any resulting changes in data accuracy, validity, and coverage, as well as operator qualitative interpretations. Should the potential upgrades occur and have a significant impact on data quality, an approach to screening and normalization of affected data will need to 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.
- Mitigating the impacts of operator turnover between pre- and post-deployment is essential. The evaluation team will minimize this factor by selecting operators who have had a longer history in association with their current positions and corridor operations. Historical operator performance will also be considered through interfacing with the operator's immediate supervisor, providing the evaluation team with a sense as to whether the operator will make a dependable, knowledgeable and willing participant in the evaluation.
- Non-ICM transportation system changes and construction or maintenance projects outside of the ICM corridors may reduce corridor capacity or change demand and, therefore, have an adverse effect on the measures associated with DMS messaging, changes in average incident response times, and changes in operators' perceived quality of information. This factor can be minimized by carefully tracking and taking into consideration such events at least qualitatively and, when possible, quantitatively. By gaining awareness of individual event specifics (start/end times, days of week, nature of event, etc.), the data collection plan can be developed in a way that the "known" traffic impacting periods are noted during data collection. This will allow the evaluation team to track and cleanse the data associated with such events in order to examine the causal effects between the events and underlying MOEs vs. ICM strategies and the MOEs.

5.1.4 Issues

Data to support qualitative analyses will be collected via interviews, surveys and discussion groups with operators, and by on-site observations. Given that operators' perceptions of the ICM System will be subjective, development of well-designed questionnaires to minimize personal interpretation as much as possible will be essential to avoid biased evaluation results. Operator perceptions will only be considered valid if they can point to actual outcomes that support their perceptions.

Another key issue in this analysis is the availability of and level of detail in operator and event logs. The evaluation team has reviewed the sites' system requirement documents and it appears that many, but not all, real-time operator log data desired by the national evaluation team (see Table 5-1) are currently planned for inclusion in the ICM systems. Both sites have expressed concerns about distracting operators with real-time, manual logging activities. The national evaluation team understands and shares that concern and therefore it will be important during test plan development to find ways to collect vital data while keeping distraction to an absolute minimum. Options that will be explored with the site during test plan development include: 1) Maximizing the use of built-in system logging functions (applies primarily to post-deployment), 2) Finding mutually-agreeable ways to minimize operator distraction by keeping the manual logging as low-impact as possible, such as by using a limited number of check boxes, and 3) As a last resort, dropping any real-time, manual operator logging found to be too distracting and for which no mitigation is identified.

In addition to minimizing operator distraction, it will be very important to devise consistent instructions, procedures, formats, and training to all operators involved with ICM operations so as to promote consistency in log keeping. The national evaluation team assumes the operating agencies will instruct and train operators to keep logs on their activities. There is a possibility that the instructions and training for operators may not be consistent across agencies, shifts and from operator to operator. The information logged and the level of details in the logs may also be inconsistent among operators. This may pose challenges to the evaluation team to obtain consistent and needed information to the analysis. It will be critical for the sites in concert with the evaluation team to devise consistent instructions, procedures, formats, and training to all operators involved with ICM operations. However, this may still not alleviate the possibility of some operators not adhering completely to the instructions and procedures.

5.2 Decision Support Systems

This analysis is one of the two evaluation analyses that focuses exclusively on "outputs"—the capabilities acquired by the transportation operators as a result of ICM deployment. This analysis focuses on the decision support systems to be implemented by both sites.

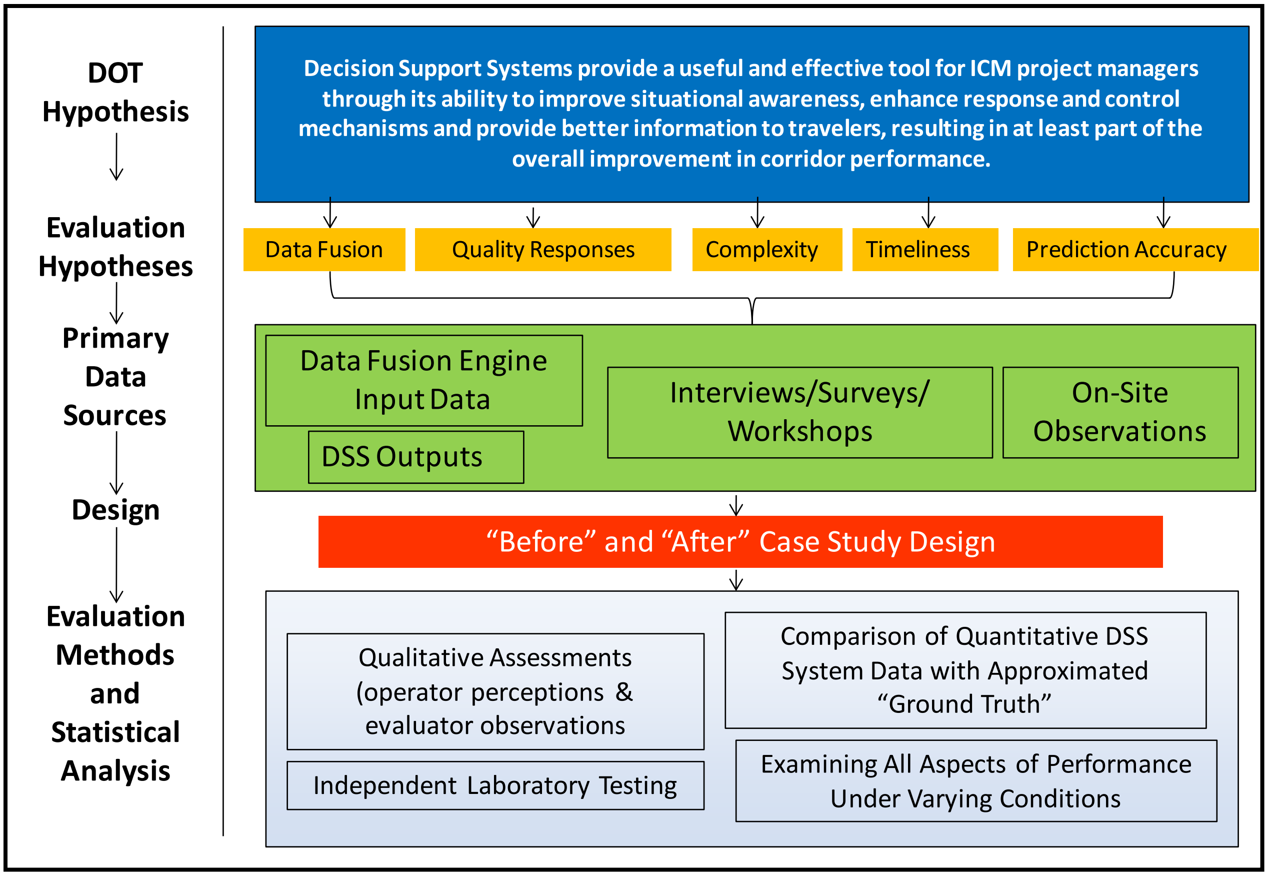
Information sharing capabilities, including providing actionable information to travelers, and the ability to manipulate transportation capacity such as by adjusting traffic signal timing or adding short-term transit capacity are crucial to ICM success. However, decision support systems can be considered the "heart" of ICM. They provide the critical information synthesis and decision making support necessary for transportation operators 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 must include predictions of the results of alternative response plans. This analysis will thoroughly explore specific performance characteristics of DSS and the overall contributions of DSS to ICM success at both sites. This will include investigation of the ability of each sites' data fusion engine to effectively fuse data, the quality of responses generated by the DSS, the accuracy of DSS predictions of transportation system conditions 30 minutes or more into the future, 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. However, the Technical Capability Analysis (Section 5.1) does include before-after comparisons of changes in the ability to monitor conditions and take appropriate control actions, including changes related to DSS.

This DSS Analysis will include:

- Operators' assessments of the performance and value of ICM, including advantages and disadvantages relative to pre-ICM methods and, if circumstances allow, post-ICM with and without various DSS functionality and application.
- Laboratory analysis of DSS data fusion performance, comparison of DSS predictions to the best approximation of "ground truth" that is available, and use of time-stamped DSS system data to determine speed of DSS performance.

Figure 5-2 provides a summary of this analysis area and provides context for the rest of this section linking hypotheses, data sources, design, and analysis approach.



Battelle, May 7, 2012

Figure 5-2. Overview of DSS Analysis

5.2.1 Evaluation Hypotheses

As indicated in Figure 5-2, U.S. DOT has a single, broad hypothesis relative to the DSS' role in ICM:

> *"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 in at least part of the overall improvement in corridor performance."*

This analysis has disaggregated this high-level hypothesis into several more discrete, measurable hypotheses that can be individually tested and examined. Those hypotheses fall into the following five areas:

- Data Fusion
- Quality of DSS Responses
- Predictive Accuracy
- Timeliness
- Performance Under Varying Conditions.

Specific hypotheses under each area are shown in the second column in Table 5-2.

Although there are no hypotheses focusing specifically on the ability of DSS to aid in the identification and prioritization of emerging transportation system problems, the national evaluation does include MOEs that will shed light on that aspect of DSS performance. Specifically, the Technical Capability Analysis includes various measures pertaining to situational awareness and monitoring that focus on “identifying” problems. The “prioritization” of problems is currently understood by the evaluation team to be an implicit part of the sites’ DSS recommendation of response plans (rather than an explicit, discrete and directly measurable aspect of DSS performance. As such, this DSS analysis does include MOEs that will inform the understanding of DSS “prioritization” performance but they focus on the quality of the DSS-recommended responses, including accuracy of predictions associated with response plan recommendation and operators’ perception of the appropriateness of the DSS-recommended responses.

5.2.2 Key MOEs and Data

Each evaluation hypothesis has been linked to one or more key MOEs and the sources for the data needed to develop the MOEs. This information, presented in Table 5-2, is based on preliminary conversations with the deployers at both sites and with U.S. DOT. As the sites’ ICM system designs progress and as the development of evaluation test plans begin, this information will be refined, including any site-specific modifications. In assessing each MOE, consideration will be given to MOE performance according to different types of events or disruptions, e.g., data fusion performance will consider a range of circumstances such as high-demand, incident, etc.

Table 5-2. DSS Analysis Hypotheses, MOEs, Data and Sources

Hypothesis Area	Evaluation Hypotheses	MOE	Unit	Data	Data Source
Data Fusion	DSS can take data from disparate sources, standardize/clean it, and turn it into an interpretable and mutually comparable format, successfully recognizing overlaps and gaps in the data streams	Successful rate of data fusion engine in taking data from disparate sources	Percentage	Data fusion engine inputs and outputs, Laboratory analysis outputs	Data fusion engine inputs and DSS outputs, Evaluator's lab test outputs
		Successful rate of data fusion engine in standardizing data	Percentage	Data fusion engine inputs and outputs, Laboratory analysis outputs	Data fusion engine inputs and DSS outputs, Evaluator's lab test outputs
		Successful rate of data fusion engine in recognizing overlaps in data	Percentage	Data fusion engine inputs and outputs, Laboratory analysis outputs	Data fusion engine inputs and DSS outputs, Evaluator's lab analysis outputs
		Successful rate of data fusion engine in recognizing gaps in data	Percentage	Data fusion engine inputs and outputs, Laboratory analysis outputs	Data fusion engine inputs and DSS outputs, Evaluator's lab analysis outputs
Quality of DSS Responses	DSS suggests multiple reasonable strategies and provides the human decision-makers with the relevant information to choose between them	Perceived quality of responses, including improvement relative to any comparable pre-ICM approaches	None (qualitative)	Operators' perceptions of the quality of responses generated by DSS, operators' perceptions of the improvement in response quality relative to pre-ICM response plans	Interviews/surveys with operators and agency staff
		Percentage of responses consistent with operators' experience and expectations	Percentage	Operators' perceptions of the responses generated by DSS	Interviews/surveys with operators and agency staff
		Percentage of times operator implements recommended responses	Percentage	DSS output, agency response records and logs	DSS, Agency response records, Agency logs
		Percentage of times operator alters recommended responses	Percentage	DSS output, agency response records and logs	DSS, Agency response records, Agency logs
		Perceived usefulness of information provided to operators for interpretation and decision making, including improvements relative to pre-ICM approaches	None (qualitative)	DSS output, operators' perceptions of the quality of responses generated by DSS, operators' perceptions of improvement s relative to pre-ICM/DSS approaches	Interviews/surveys with operators and agency staff
		Level of operator intervention in altering recommended responses	None (qualitative)	DSS output, agency response records and logs, Operators' perceptions	DSS, Agency records and logs , Interviews/ surveys with operators and agency staff

Table 5-2. DSS Analysis Hypotheses, MOEs, Data and Sources (Continued)

Hypothesis Area	Evaluation Hypotheses	MOE	Unit	Data	Data Source
Predictive Accuracy	DSS describes the effect of the various responses accurately	Difference between predicted outcomes and actual operation conditions in terms of corridor performance (volumes, speeds, travel times, and throughput) in various scenarios	Percentage or actual value	DSS simulated output, actual field conditions from agency detection and monitoring systems, reported mobility measures, AMS model outputs	DSS, Transportation system data, results from the Mobility Analysis
		Perceived accuracy of predictions	None (qualitative)	Operators' perceptions of the accuracy of predicted outcomes	Interviews/surveys with operators and agency staff
Timeliness	DSS provides recommended strategies with simulated results quickly and any steps that require human intervention can be completed expediently and easily	Average time for DSS to deliver an actionable response plan	Milliseconds, seconds, or minutes	Data input timestamps, DSS output timestamps	Data fusion engine inputs, DSS outputs
		Average time for DSS to deliver predictions of strategy outcomes	Milliseconds, seconds, or minutes	Data input timestamps, DSS output timestamps	Data fusion engine inputs, DSS outputs
		Perceived level of human intervention required during the DSS' development of an actionable response plan	None (qualitative)	Perceptions of required human intervention	Interviews/surveys with agency staff
Performance Under Varying Conditions	DSS works in recurring as well as non-recurring congestion conditions when things are most unpredictable and rapidly changing	All of the above MOEs in recurring congestion scenarios	See above	All of the above	All of the above
		All of the above MOEs in non-recurring congestion (incident, adverse weather, special events, construction) scenarios	See above	All of the above	All of the above

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The MOE language in Table 5-2 is intentionally non-site specific. As the site-specific, detailed test plans are developed generic terms such as "operator" will be changed to site-specific terms such as, in the case of Dallas, "ICM Coordinator." Test plan development will also take into consideration finer differences between the sites' DSS functionality and expected utilization. For example, as described in Section 2.3.1, it is possible that the Dallas DSS predictive data presented to the ICM Coordinator may, at least for the early portion of the post-deployment evaluation period, consist of more "binary" predictions of whether a given response plan will have a net positive benefit or not, rather than a comprehensive picture of predicted impacts. In another example, the MOE in Table 5-2 related to operator intervention in altering recommended response plans will be refined in the Dallas DSS Analysis Test Plan to reflect the understanding that there may be limited real-time (during an event) ICM Coordinator or other transportation operator tweaking of response plans.

As indicated in Table 5-2, this analysis will require both pre- (data fusion engine input) and post-processed (DSS outputs—response plans) data associated with the ICMS and DSS. Data fusion engine input data refers to the raw transportation system data that is fed into the Dallas data fusion engine, including any sensor, probe, signal system, parking, transit, incident, travel time and other input data. To enable independent laboratory assessments of data fusion capability and predictive accuracy, the evaluation team will need to collect this input data from each site, preferably in real-time so that it may be processed and analyzed as would the actual fusion engines. This data will need to be collected for a comprehensive set of data fusion engine/DSS operating conditions, including major incidents, minor incidents, etc. These scenarios and the procedures for the national evaluation team receiving the data fusion engine inputs will be determined in consultation with the deployers during evaluation test plan development. The evaluation team will also require data fusion engine and DSS output data, meaning, the "fused" data flowing out of the data fusion engine and the response plans and recommendations flowing out of the DSS. In all cases, the above mentioned raw input, and processed output data will need to be time-stamped.

The other major type of data identified in Table 5-2 is operators' perceptions of DSS performance and value. These include perceptions of the quality of response strategies generated by the DSS and the operators' perspectives on how much of their intervention with the DSS is required as part of generating and modifying response strategies. Operator perceptions will be collected through in-person interviews, surveys of the operators, and agencies' response plan logs and other agency event logs. These interviews will be coordinated with other interviews included in the evaluation, including those associated with the Technical Capability and Institutional and Organizational Analyses.

5.2.3 Analysis Approach

Since there are no DSS currently being used at either site, there is no "pre-ICM" DSS performance data available and, therefore, at the highest level, this analysis can be considered a case study comparing information synthesis and response plan selection techniques before and after DSS. In addition to investigating the value of DSS relative to pre-ICM conditions, the analysis will also document the performance of the DSS itself across a number of dimensions using both quantitative and qualitative (operator perception) data. This analysis will also attempt to determine the marginal value of DSS within the post-ICM condition, that is, to determine how much more DSS adds above and beyond the other ICM investments; how critical a DSS and DSS performance is to the overall ICM concept. Analysis activities fall into the following two categories, which are further discussed below: 1) operators' assessments of the performance and value of ICM and 2) laboratory analysis of DSS data fusion performance and the timeliness of DSS generation of response plans and predicted conditions.

One of the major issues impacting the development of this draft framework, and more significantly the test plans that will follow, is the current uncertainty on the part of the national evaluation team regarding the sites' plans for use of DSS in a real-time capacity. That is, plans for developing and/or revising response plans using DSS in real-time during a specific incident or event. Conversations to date with the deployers indicate that generation of a pre-defined "menu" of response strategies appropriate to various scenarios is a core component of their DSS strategy, but plans for real-time application of DSS are unclear. Also, a related uncertainty concerns the use of the predictive capability of the DSS. It is not clear whether the DSS will predict future conditions only within the context of recommending a response plan—that is, to forecast conditions 30 minutes out assuming no intervention so as to determine what sort of response is required—or whether the DSS will also provide an output prediction of what the future conditions will be as a result of response plan implementation. The draft analysis approach presented here assumes that prediction will occur in both respects.

5.2.3.1 Operator Perceptions

Candidate methods for collecting operator perceptions of DSS, which will be finalized in consultation with the deployers during test plan development, include the following:

- **Operator logs.** For the pre-deployment period, the operators will be asked to log their activities in terms of the nature of the events, reactive strategies (response plans), time spent on determining and implementing the response plans, and other actions and strategies implemented following the initial response plan implementation. During the post-deployment period, these logs, or tracking sheets, will focus on such topics as level of DSS operator intervention, perceived quality and accuracy of DSS outputs, and perceived accuracy of predicted outcomes, amongst other topics. A written, clear definition of how the grading scale should be applied to each operator's entries will accompany the form and the evaluation team will provide instruction to the deployers in regard to completing the logs, both of which will help to mitigate interpretive differences between individual operators. Since operators are very busy during incident conditions, it will be critical to find ways to obtain the necessary log information while minimizing the distraction and time commitment for operators. This can include building logging functions (e.g., text fields, check boxes, etc.) into the DSS and other software systems with which the operators interact and/or taking advantage of logs that are currently maintained. These issues will be an important point of discussion with the deployers as the test plans are developed.
- **Operator and agency personnel interviews.** These interviews will focus on specific scenarios—case studies—documented in specific portions of the operator logs. In addition to complementing the data collected via the operator logs, these interviews will also probe the staff on the presence and influence of exogenous factors on DSS operation, performance and their own valuation of DSS. These exogenous factors include circumstances influencing their ability to operate DSS as intended and/or to implement the response plans recommended by the DSS, including staff turnover, staffing shortages or other resource constraints and agency policy changes. At least one round of interviews will be conducted during both the baseline (pre-ICM) and post-deployment time periods. In so much as the interview sessions will focus in part on cases of DSS application during specific incidents/events, scheduling of the interviews will be determined through the analysis of DSS system data and operator logs and selection of case studies.

A descriptive analysis will be conducted to evaluate operators' and agency staff perceptions towards DSS. This analysis will take the form of descriptive statistics to describe and summarize perception data.

DSS **s**ystem data will be collected that will provide a context for the operator perceptions collected through the aforementioned logs and interviews. This will include system data documenting the number and type of incidents/events occurring pre- and post ICM deployment, the percentage of DSS response plans that were accepted by operators, and the number of times an operator altered a DSS response plan based on their experience.

5.2.3.2 Laboratory Analysis

The evaluation team will conduct an independent, in-depth laboratory assessment of the effectiveness and appropriateness of each site's capability for and approach to data fusion and situational awareness. A sampling of each site's data fusion engine input data will be taken and fed into other data fusion engines, including the University of Maryland Center for Advanced Transportation Technology Laboratory's Regional Integrated Transportation Information System, and their fusion outputs and methodologies will be evaluated and compared with those of each site's fusion engines. This laboratory testing will focus on assessing the data fusion capabilities of each site's ICMS, including their ability to successfully synthesize a wide range of data types, recognize and address gaps and overlaps, and otherwise process the data so it can be used by the DSS to recommend and revise response plans. The laboratory analysis will also investigate the timeliness and predicative accuracy of the DSS. As noted earlier, this will require collection, preferably in real-time, and for a to-be-determined set of scenarios/case studies, the same stream of ICM system data that is input to each site's DSS. The particulars of that data capture will be an important area for discussion and finalization with the deployers during test plan development.

Data fusion testing will compare the data fusion output to the input data, focusing on how much data was taken from various sources, the percentage of data that was successfully standardized and fused, and the fusion engine's treatment of overlaps and gaps. Results will be presented both quantitatively and qualitatively. Graphics may be used to show which data elements are or are not being fused accurately. More qualitative measures and case-studies may be used if there are other fusion approaches that may have warranted further study or investigation by the ICM site. Case-studies may also be used to show how other fusion methods may have been inferior to the chosen fusion engine at the ICM site. Input data will be compared with output data to evaluate accuracy in data fusion. Discrepancies will be quantified especially in instances where data is being interpolated or there is a reliance on historical measures. When multiple inputs for a single location are present, a comparison of how the data is "combined" and validated will also take place.

Laboratory analysis of the timeliness of the site's DSS in recommending strategies and providing predicted results of strategy recommendations will be performed. Timeliness measures will be presented in both graphical and matrix form. It will be critical to compare timeliness at varying levels of complexity and rank them accordingly. The timeliness of collection, fusing, and disseminating will be analyzed through the use of data timestamps. An analysis will be conducted on the time at which the data is transmitted from the field to the data aggregation/data fusion component of each site's ICMS and then a strategy or a set of strategies is presented to the operator. This will be done through the use of a comparison of timestamps from data inputs and outputs.

The laboratory analysis will also examine DSS predictive accuracy. A comparison of the predicted outputs to actual measured values from the system data (traffic counts and other data input to the ICM systems and DSS) will be checked. Where discrepancies exist, they will be quantified and evaluated for statistical significance and/or measurement errors. Measures referring to the accuracy of the DSS including the comparison of predicted to actual outcomes will be presented in graphical, tabular, and case-study reports. Graphics will likely include the bar, pie, and other charts comparing time-of-day performance, complexity performance, etc. Case studies will be presented in such instances where unique situations present themselves that highlight DSS success stories or failure stories. It is hoped that such case studies may shed light onto why the DSS was successful or what might be done to prevent future failure—depending on the outcome of the analysis. Careful consideration will be given to the time-of-day and specific conditions under which the DSS is analyzed. Evaluators will give special attention to DSS outputs and performance during peak periods.

5.2.4 Issues

The collection of data for this analysis poses several key challenges that will need to be addressed as test plan development proceeds. These challenges include the following:

- **Availability of and consistency in operator logs.** The approach proposed here assumes that operator logs will be available. Both sites have expressed concerns about distracting operators with real-time, manual logging. The national evaluation team understands and shares that concern and therefore it will be important during test plan development to find ways to collect vital data while keeping distraction to an absolute minimum. Options that will be explored with the site during test plan development include: 1) Maximizing the use of built-in system logging functions (applies primarily to post-deployment), 2) Finding mutually-agreeable ways to minimize operator distraction by keeping the manual logging as low-impact as possible, such as by using a limited number of check boxes, and 3) As a last resort, dropping any real-time, manual operator logging found to be too distracting and for which no mitigation is identified. In addition to minimizing operator distraction, it will be very important to devise consistent instructions, procedures, formats, and training to all operators involved with ICM operations so as to promote consistency in log keeping. The approach proposed here assumes the deployers will play an active role in developing and conveying that instruction and in monitoring operator compliance and consistency.
- **Availability of both raw and processed data in a form easily accessible to the evaluation team.** It will be important as test plans are developed to work with the deployers to specify the sampling approach, including what time periods are to be sampled and the total amount of data to be collected, as well as the technology mechanism for transmitting the data to the evaluation team. Completing the proposed analysis within the constraints of the evaluation resources will rely on easy access to the required data.
- **Additional detail on planned DSS functionality and tracking through the design and implementation process.** Many of the national evaluation team's early questions on the sites' specific plans for DSS functionality, especially related to predictive and real-time

uses, have been clarified. However, there are still some aspects of DSS functionality which will need to be further discussed during test plan development and tracked as the sites' design and implementation processes continue after test plans are developed.

- **Time-stamping of system data.** It is critical that timestamps exist on the data for when it was collected and/or generated. Timestamps for when data is transmitted to the evaluation team will not be sufficient to allow for proper analysis.

5.3 Traveler Response

This section presents the proposed approach to the Traveler Response Analysis. One of the core tenets of the ICM Initiative is that better informed travelers will utilize this information to optimize their personal travel. This in turn, will have the resulting impact of improving travel and performance characteristics across the entire corridor. Travelers' response to system perturbations with and without ICM, including (to the extent feasible) their response to specific strategies, is therefore integral to ICM success and is a key aspect of this evaluation, supporting both the evaluation findings report and the AMS model validation efforts.

Within the context of ICM, the response of travelers can be influenced by many factors including those that can be attributed to the ICM strategies as well as other factors that are exogenous to the ICM deployment (e.g., weather). Traveler response can be viewed both as an "effect" of ICM strategies, as well as a "cause" to network performance that can lead to system-wide benefits. For example, for there to be system-wide mobility improvements, a significant portion of the traveling public will need to be aware of and change behavior as the traffic conditions change so that a system-wide improvement in mobility can be realized. In other terms, traveler response is important to evaluate not only in the context of its impact to the individual traveler in outcomes such as total travel time, and travel time reliability, but also within the context of the larger system outcomes such as increased person throughput, resources utilization, and safety benefits.

Both impacts on individual travelers—that is, individual travelers' reaction to ICM—and cumulative impacts (among many travelers) on the performance of the transportation system, will be examined as part of the evaluation. The analysis described in this section, however, focuses on the impact on individuals or groups of travelers as a result of implementing one or more ICM strategies, rather than examining system-wide changes for which a change in traveler response is a necessary prerequisite. These systemic changes are implicitly included in the other evaluation areas, such as the analyses related to mobility, and are, therefore, not discussed in detail in this analysis section. However, it is important to note that a significant portion of the data collected through the mechanisms discussed in this analysis will also be important in the other analyses (e.g., Corridor Performance) to provide a context for observed system/corridor/facility impacts, including helping to understand the influence of exogenous factors.

5.3.1 Evaluation Hypotheses

As illustrated in Figure 5-3, U.S. DOT has defined an overall hypothesis for assessing Traveler Response as:

> *"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."*

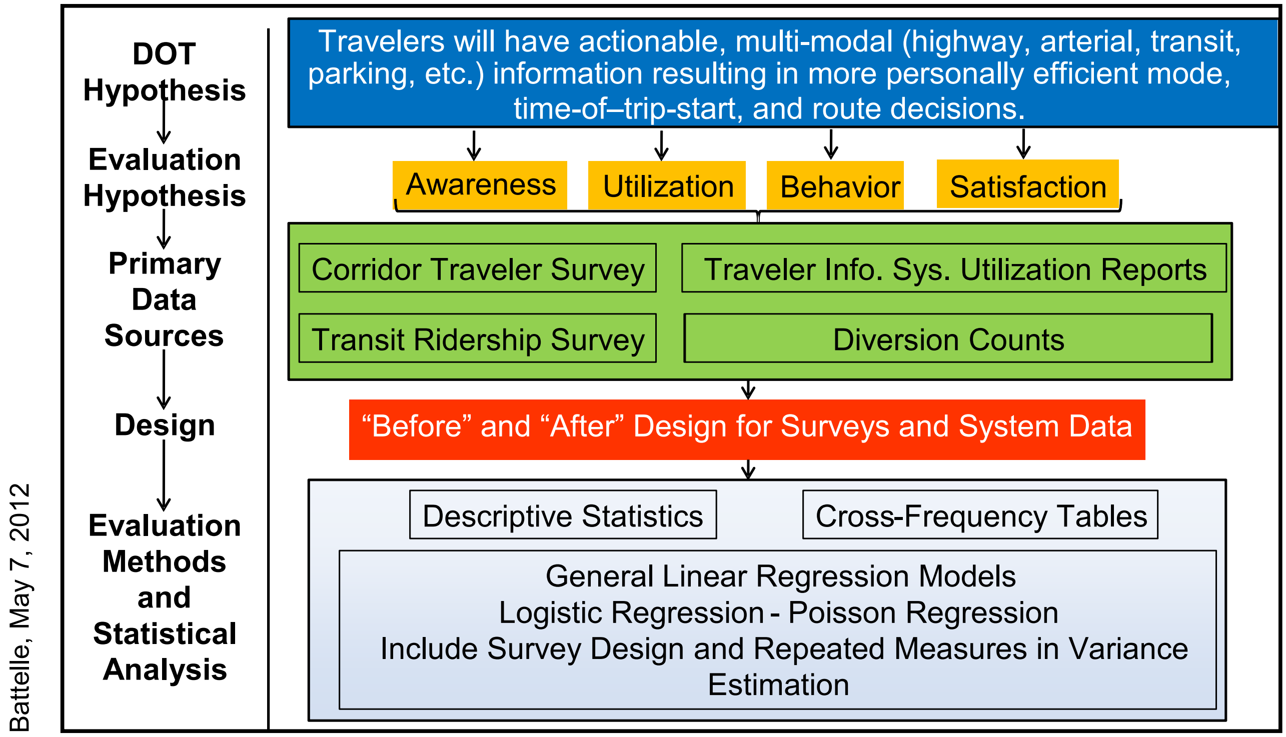

Figure 5-3. Overview of Traveler Response Analysis

The evaluation approach described in this section builds upon the specific U.S. DOT hypothesis by partitioning it into a series of hypotheses that can be individually and collectively tested. For convenience, these hypotheses are grouped into four general categories focused upon:

- **Awareness.** This group of hypotheses assesses the extent to which the general traveling public is aware of ICM delivery mechanisms being employed. Additionally, this set of hypotheses also seeks to address whether the public is aware of the actual information that is being provided (e.g., aware of travel options).
- **Utilization.** Utilization in this context means that the traveler somehow *uses* the information obtained through the ICM strategies or other sources to make a travel decision. Use in this context does not imply any actual change in behavior, which is assessed through different hypotheses, just the extent to which the traveling public is a consumer of the information provided.

- **Behavior.** Ultimately, changing the behavior of travelers through the implementation of ICM strategies is one of the major goals of the ICM deployment as this change is a primary mechanism for achieving gains in system performance. These hypotheses assess whether the enhanced information provided through the implementation of ICM strategies results in changes in traveler behavior.
- **Satisfaction.** This set of hypotheses is focused upon assessing how satisfied the traveling public is with their traveling experience and whether that satisfaction has changed as a result of an ICM strategy.

Specific evaluation hypotheses within each of these four areas are shown in Table 5-3.

Table 5-3. Traveler Response Evaluation Hypotheses

Evaluation Hypothesis Area	Evaluation Hypotheses
Awareness	Self-reported traveler awareness of traveler information sources will increase post deployment of ICM.
	Transit users will report awareness of traveler information enabled or enhanced by deployment of ICM.
Utilization	The deployment of the ICM will result in a greater number of travelers using information systems.
	Transit users will report utilization of traveler information enabled or enhanced by deployment of ICM.
Behavior	Travelers will be more likely after ICM deployment to have used added or enhanced ICM assets to change mode, route, or timing of trips.
	Transit travelers will report after ICM deployment having used added or enhanced ICM assets to change mode, route, or timing of trips.
Satisfaction	Travelers will be more satisfied with the type and reliability/accuracy of the travel information that they receive from sources after ICM deployment.
	Transit users will be satisfied with travel information after ICM deployment.
	Travelers will be more satisfied with their travel experience (e.g., predictability of travel time and travel speed) after the ICM deployment.
	Transit users will be satisfied with their overall travel experience after ICM deployment.

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5.3.2 Key MOEs and Data

Each hypothesis within Table 5-3 in Section 5.3.1 has been linked to one or more key measures of effectiveness and data sources in Table 5-4. This table is expected to be further refined during the development of detailed test plans to link specific hypotheses to implementation details regarding traveler information mechanisms.

As part of the overall evaluation effort, the evaluation team along with Volpe and the ICM sites will collaborate on the development of the survey efforts including questionnaire development and design. Similar work will be done with the ICM site teams to identify how the non-survey data may best be obtained.

Table 5-4. Traveler Response Hypotheses, MOEs, Data and Sources

Hypothesis Area	Evaluation Hypotheses	MOE	Data	Data Source
Awareness	Self-reported traveler awareness of traveler information sources will increase post deployment of ICM.	Change in awareness of travel information sources	Survey responses pre- and post-ICM	Corridor Traveler Surveys
		Change in awareness of travel information sources related to incident/event conditions		Pulse Surveys
	Transit users will report awareness of traveler information enabled or enhanced by deployment of ICM.	Transit user awareness of travel information sources	Survey responses post-ICM	Transit Surveys
Utilization	The deployment of the ICM will result in a greater number of travelers using information systems.	Reported utilization to include frequency of uses by source	Survey responses pre- and post-ICM	Corridor Traveler Surveys
		Reported utilization to include frequency of uses by source related to incident/event conditions		Pulse Surveys
		Changes in the number of calls, accesses, and registrations related to the corridor over time.	Legacy phone and web, 511 phone and web, and social media traveler information statistics	Traveler Information Usage Statistics
	Transit users will report utilization of traveler information enabled or enhanced by deployment of ICM.	Reported utilization to include frequency of uses by source	Survey responses post-ICM	Transit Surveys
Behavior	Travelers will be more likely after ICM deployment to have used added or enhanced ICM assets to change mode, route, or timing of trips.	Change in behavior with regard to selection of mode, route, or timing	Survey responses pre- and post-ICM	Corridor Traveler Surveys
		Change in behavior with regard to selection of mode, route, or timing related to incident/event conditions		Pulse Surveys
		Change in the percentage of drivers diverting to avoid an incident location in response to dynamic message sign	Traffic volumes upstream and downstream of a diversion point	Traffic Diversion Data
			Incident data related to a diversion scenario	
	Transit travelers will report after ICM deployment having used added or enhanced ICM assets to change mode, route, or timing of trips.	Perceived change in behavior with regard to selection of mode, route, or timing	Survey responses post-ICM	Transit Surveys

Table 5-4. Traveler Response Hypotheses, MOEs, Data and (Continued)

Hypothesis Area	Evaluation Hypotheses	MOE	Data	Data Source
Satisfaction	Travelers will be more satisfied with the type and reliability/accuracy of the travel information that they receive from sources after ICM deployment.	Changes in satisfaction profile	Survey responses pre- and post-ICM	Corridor Traveler Surveys
		Changes in satisfaction profile related to incident/event conditions		Pulse Surveys
	Travelers will be more satisfied with their travel experience (e.g., predictability of travel time and travel speed) after the ICM deployment.	Changes in satisfaction profile		Corridor Traveler Surveys
		Changes in satisfaction profile related to incident/event conditions		Pulse Surveys
	Transit users will be satisfied with travel information after ICM deployment.	Perceived change in satisfaction	Survey responses post-ICM	Transit Surveys
	Transit user will be satisfied with their overall travel experience after ICM deployment.	Perceived change in satisfaction		

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5.3.3 Analysis Approach

There are several different analyses that will be conducted within the Traveler Response evaluation area. The bulk of the analysis will focus upon information gathered through traveler surveys being conducted by the Volpe Center. Other separate analyses will be conducted using data captured through the other mechanisms presented in Table 5-3, including usage data from information dissemination mechanisms (e.g., 511), and a proposed traffic diversion measurement scenario to assess behavior change. The remainder of this section is organized around these three specific data sources.

5.3.3.1 Traveler Behavior Surveys

The primary data sources for assessing the hypotheses associated with Traveler Response are the traveler behavior surveys being conducted by the Volpe Center. The sections below discuss the form and basic nature of these surveys as well as the statistical analysis to be done on the survey data.

5.3.3.1.1 Traveler Behavior Survey Format

Survey activities will include a panel survey of drivers (including “regular use” and specific traffic incident-related “pulse” surveys) and transit users. Each of these is described in the sections that follow.

5.3.3.1.1.1 Panel Survey (Drivers)

The overall design is a panel survey of drivers to capture changes due to ICM. The survey will be administered in waves, with a baseline survey during the pre-deployment period and a final survey of the same respondents (to the extent feasible) in the post-deployment period. Additionally, the Volpe Center approach to the traveler surveys includes “pulse” surveys in which the same panel members will be surveyed regarding specific events that occur during peak hours and that impact travel in the corridor. The surveys will be conducted within a short time after the event occurs. The pulse surveys are planned to be administered at multiple times in the pre- and post-deployment phases, with the expectation that multiple responses (pertaining to multiple events) will be received from each respondent during the pre- and post-deployment pulse surveys.

The population of interest is regular, peak hour users of the corridor (i.e., 3 or more days/week). The population is defined as individual drivers and not households. While occasional or one-time travelers may well benefit from the ICM deployment, it is these regular users that are expected to provide the greatest sensitivity to changes in the corridor that could be attributed to the ICM deployment. Another reason to focus on these regular, peak hour users is due to the study design, which features the use of pulse surveys. By focusing on regular, peak hour users, the likelihood that respondents are traveling in the corridor when there is an incident and, thus, are able to participate in the pulse survey is maximized.

Driver sampling is planned to be done by license plate capture on the corridor. Intercepted plates will be sent to the division of motor vehicles within the state government to obtain the matched names and addresses of the vehicle owners. Those owners will then be invited to participate in the study. A sufficient number of drivers will be recruited in order to obtain a final sample size of approximately 900 freeway drivers and 500 arterial drivers.

The planned sample size is expected to be sufficient to provide results of adequate precision. The precision of reported results is impacted by many factors including the type of survey measure (e.g., categorical vs. continuous measurement), survey weighting, and the observed results. However, a simplified example of the expected level is as follows: Assuming the survey question is a binomial response (e.g., yes or no) with corresponding percentage estimated for each outcome, and the true (but unknown) percentage for each response is near 50 percent, a sample of 500 might result in a margin of error (i.e., result is reported as “x” proportion with 95 percent confidence of (“x”-margin) to (“x”+margin)) of about 4.4 percent. At sample size of 900, the margin of error would be about 3.3 percent. For the combined 1400 samples, the margin of error could be 2.6 percent.

The specific questions that make up the questionnaires have yet to be determined. However, questions for the baseline and final surveys will include demographics, technology ownership, attitudes and values, schedule flexibility, typical use of the corridor, awareness of traveler information, use of traveler information, travel behavior decision making, and traveler satisfaction. Questions for the pulse surveys will include use of travel information, travel behavior decisions, and traveler satisfaction.

5.3.3.1.1.2 Transit Survey (Riders)

Surveys of transit riders will be performed to capture changes due to ICM. The study population is regular, peak hour users of the relevant transit system. The transit survey will begin as an on-board intercept survey with sampling locations at transit terminals. Participants will be asked a limited number of questions en route and then will be encouraged to complete a more comprehensive follow-up survey online with a telephone option. Additional language options besides English will be made available to respondents to complete the survey by telephone. A sufficient number of transit riders will be recruited in order to achieve a final sample size of approximately 500 riders. This sample size is expected to provide adequate precision for reported results. As discussed above, a sample of 500 is adequate to produce a maximum 4.4 percent margin of error for a common binomial proportion result (e.g., yes or no). Surveys will be administered in the post-deployment period as pulse surveys, aligned to driver pulse survey events if possible.

The specific questions that make up the questionnaires have yet to be determined. However, questions will include demographics, technology ownership, attitudes and values, schedule flexibility, typical use of the corridor transit and reason for use, awareness of traveler information, use of traveler information, travel behavior decision making, and traveler satisfaction.

5.3.3.1.2 Statistical Analysis of Traveler Survey Data

Under the panel survey, a sample of travelers will be recruited and surveyed at both ICM deployment sites before, during, and after the ICM strategies are deployed. The use of a panel design provides a mechanism for estimating the "within participant" variability, which is equivalent to having each person serve as their own "control." This technique is particularly useful when attempting to measure relatively small, but meaningful, changes in the presence of other exogenous factors that would otherwise tend to overwhelm the change being measured. Statistical analysis of the information collected through the panel surveys will be performed using standard statistical analysis software such as the SAS© system or Stata©. Importantly, all statistical analysis will be conducted using survey weights to ensure that the results can be extrapolated to a larger population as well as reducing sampling and non-response biases. Should it prove infeasible to develop survey weights that are post-stratified to the larger traveling population at the two ICM sites, statistical analysis will be conducted using survey weights that account for the sample selection probability as well as non-response but are calibrated to match the number of surveyed individuals (i.e., the weighted sample size will be equivalent to the actual sample size).

Two different types of statistical analyses will be conducted with the survey data; descriptive statistics and detailed modeling. The descriptive statistics, including frequencies, means, and quartile estimation will be provided for every questionnaire item, this will provide a simple summary for each of the measures of effectiveness. Cross-frequency tables will be prepared to conduct an initial assessment of the relationship between variables such as access of ICM-provided information sources by time of day. Statistical tests using these descriptive statistics will include t-tests as well as Chi-square-tests for cross-tabulation tables. Simple log-linear modeling will be used to conduct additional statistical tests based upon cross-frequency tables so that more sophisticated relationships between various survey responses can be examined (i.e., how the measures of effectiveness change with levels of other factors such as time of day, etc.). For example, we will utilize a log-linear model to understand and quantify the impacts of improved information dissemination as a function of social economic characteristics, geographic location of the driver's household, and length and regularity of the respondent's commute. Although extensive descriptive analyses and log-linear models will be used to produce estimates of changes in the measures of effectiveness, these results will only be considered to be preliminary and will only be produced within the context of leading to statistical analysis techniques that can account for the significant exogenous factors expected to be present during the ICM deployment period.

Controlling for exogenous factors will be conducted through the application of "mixed-models." These models are contained within the larger family of general linear models (GLM) but differ in that they include both "fixed" effects as well as "random or repeated" effects. These models are particularly useful in situations where measurements can be clustered, such as in a panel survey where responses across survey waves are considered to be clustered within a particular respondent (i.e., each respondent provides "repeated" observations across the waves). This model structure allows for partitioning the model-based estimated variance terms to account for "within respondent" and "between respondent" terms. This partitioning enhances the ability to identify statistically significant differences in the fixed effect terms.

Within the models that will be developed for these analyses, the fixed effect terms will consist of two separate types of effects: explanatory factors and blocking variables. Explanatory factors are those factors for which estimates of changes are desired (e.g., before/after ICM deployment). Blocking variables are those exogenous variables that are thought to be related to the outcome of interest, and, therefore, the impact of these variables on the outcome needs to be accounted for. The impact of these exogenous effects serves to "block" off or explain a portion of the variability in the outcome, the remainder of which is assumed to be either random variability or explained by the factors of interest. All statistical models developed for this analysis will follow the form of the equation described in Equation 1.

Equation 1. General Form of Repeated Measures General Linear Model for Estimating Traveler Response

$$Outcome = \alpha \mathrm{X} + \beta \mathrm{Z} + \delta(\mathrm{Respondent}) + \varepsilon$$

where X represents the factors of interest, Z represents a vector of covariates, δ the random effect associated with repeated observations on the same participant, and ε is the unexplained variability.

Depending upon the specific outcome being investigated, different forms of general linear models will be used. For outcomes that represent a percentage or binary outcome, logistic regression (binomial-theory based) model will be used. Count-based outcomes will be modeled using Poisson-based models. As many covariates as possible will be included in the model. The same set of covariates will be retained across all of the models. The descriptive statistics will be used to identify those exogenous variables that have a meaningful relationship with the various outcomes of interest. The following covariates will be considered as the initial set of exogenous factors for consideration:

- Demographic information
  - Age
  - Race/ethnicity
  - Gender
  - Income
  - Work status
  - Familiarity with technology
  - Length of time lived in the region
- Presence of Construction
- Seasonality
- Weather
- Availability of Travel Options, especially for routine trips (such as journey to work)
  - Alternative Routes
  - Alternative modes
  - Constraints to options (e.g., daycare or school-related limitations, job schedule inflexibility, vehicle/ride availability).

The traveler behavior survey results will include tabulated sample sizes and proportions of responses by category for each survey question. Results will be reported for the panel as a whole and separately by demographic categories and type of traveler information. Responses in the baseline period will be compared to those in the post-deployment period.

5.3.3.2 Traveler Information Usage Statistics

To provide a more comprehensive and externally verifiable understanding of travelers' consultation of traveler information (that is, "usage" in the sense of consulting the information but not in the sense of whether and how it impacts the traveler's behavior) it is useful to analyze available traveler utilization system data from the various ICM-created or enhanced dissemination outlets. Although it is possible that the ICM deployment may improve the quantity and/or quality of traveler information disseminated through a wide variety of channels, including by the media and commercial traffic information services, this analysis must focus only on those channels for which system usage data is available and can be readily collected and analyzed. Therefore, this analysis focuses on public agency telephone and web-based traveler information systems as well as social media (e.g., Twitter and Facebook) strategies. It should be noted, however, that the traveler surveys will include questions which may include responses regarding uses of commercial and media information. Therefore, these 3rd party traveler information sources will have some opportunity for inclusion in the traveler response test plan evaluation.

5.3.3.2.1 Traveler Information Usage Sources

Currently, it is not known to the national evaluation team exactly what ICM traveler information system utilization data will be available and in what format. However, the basic categories to be considered include state or local government traffic information sites, 511, transit trip planning sites, and social media dissemination outlets. Though exact details are not known, it is assumed that the typical data could include numbers of calls/user sessions by month, number of page hits to specific parts of websites, number of telephone menu selections for specific information on each corridor, and numbers of unique users/subscribers. Of high importance in each case will be the capability to allocate data to the evaluation corridor of interest (as opposed to the larger metropolitan area, for instance).

5.3.3.2.2 Analysis of Usage Data from Information Dissemination Mechanisms

The preferred analytical evaluation will be a tabulation of summary statistics on access to travel information assets during the baseline and post-deployment periods. In such cases, the statistics for the two periods can be compared to determine if they show a change or a trend suggestive of improved information dissemination following ICM deployment. This evaluation is a complementary evaluation of ICM impact as determined by the traveler surveys. The statistics collected will not be able to be definitively linked to ICM enhancements, and improvements in access could occur for reasons unrelated to ICM. However, increases in information usage occurring simultaneous to ICM deployment along with survey-related reporting of increased access will constitute a strong confirmation of the ICM-related value to improving information usage. In those cases where no baseline data are available (e.g., 511 service is new to ICM), a trend of increasing usage in the post-deployment period will provide the same sought after confirmation that ICM improves information dissemination and usage.

5.3.3.3 Traffic Diversion

To validate the outcomes of the changes in traveler behavior, it would be beneficial to go beyond the traveler survey which self-reports behavior and have a measure to objectively demonstrate ICM-influenced changes in behavior. An evaluation method is proposed that may be able to demonstrate a behavioral change directly attributable to ICM:

- Assume there is an incident on the corridor freeway that would ultimately lead to long delays.
- A DMS deployed at a point sufficiently upstream can warn travelers of the incident and the attendant back-up in enough time that drivers would be able to divert to an alternate route (e.g., HOV/HOT, frontage road, arterials) to continue their trip by car, or divert to a transit alternative.
- The proportion of freeway traffic that passes the DMS can be separated into the group that elects to exit the main freeway and the group that elects to stay on the freeway. Those that leave the freeway are said to have been diverted.
- If the rate of diversion is greater after implementation of the ICM (for a similar incident where the DMS in the pre-deployment period did not provide the ICM-enhanced guidance), it will provide some evidence that the DMS message is directly linked to drivers changing their behavior in response to an ICM enhancement.

This evaluation scenario provides a strong linkage between an ICM-related cause (DMS message to re-route in response to an incident) and a behavior change (diversion). The behavior change could occur as a result of other ICM assets (e.g., 511 mobile alerts), but the certainty of the contributions of these are not readily measurable, whereas it is reasonable to suppose that a sizable majority of drivers passing a DMS will be aware of it. For this reason, this scenario is posited to have a reasonable chance of confirming the evaluation hypothesis of a differentially higher change in behavior after ICM deployment (if one exists).

The traffic diversion scenario for assessing behavior change presents issues in both the data identification and analysis stages. Each is discussed separately below.

5.3.3.3.1 Traffic Diversion Scenario Data

There are many challenges associated with identification of a suitable location for the measurements. Some of these include:

- A suitable scenario for diversion must exist in the first place.
- The diversion scenario needs to occur multiple times both before and after ICM deployment so the comparative diversion can be observed. This also implies that the incident is of sufficient seriousness that a substantial number of drivers could be induced to divert.
- There must be a means to measure the proportion of the traffic volume that has been diverted in the scenario. This might be achieved if the main freeway and all entrance and exit ramps were instrumented for traffic counts, but this will not necessarily be the case. Instead, a more realistic scenario may be one with traffic volumes on the freeway upstream and downstream of a diversion point where the diversion point acts as a traffic sink and where no other entrances exist between the two traffic count locations.
- A DMS must be in place upstream of the diversion point, preferably close to the upstream traffic counter so it can be certain that no new drivers entered the freeway after the DMS and before the diversion since such drivers could not be assumed to be informed of the scenario.
- The DMS must provide enhanced information after the ICM deployment as compared to before. To get the greatest sensitivity, a blank or non-traffic condition related message pre-deployment would be best.

5.3.3.3.2 Traffic Diversion Scenario Statistical Analysis

Diversion will be measured for specific incidents where it is assumed that use of ICM technology either could (baseline) or did (post-ICM deployment) result in improved travel efficiency by changing driver behavior to either divert to another route or to move to another mode. Each incident will be examined individually to determine timing and location issues that are unique to it.

Diversion percentage is evaluated as follows:

$$D = 100 * (V_{upstream} – V_{downstream}) / V_{upstream}$$

Where

$V_{upstream}$ is the volume of traffic (vehicles per minute) on the freeway that are seeing their first diversion opportunity

$V_{downstream}$ is the volume of traffic (vehicles per minute) on the freeway that passed the diversion point remaining on the freeway

To properly calculate this statistic, it is critical that no sources of new traffic, or additional exits exist between the location of the before and after measurements. Furthermore, in the post-deployment period, it is important that any behavior-inducing messages have had the opportunity to be seen by everyone approaching the before location. For instance, an entrance ramp on the freeway after a DMS but prior to the "before" location would be problematic as these entering drivers would not have had access to the DMS and, hence, not be aware that they were driving toward the diversion scenario.

If a sufficient number of diversion statistics can be attained in the pre and post-deployment periods, a nonparametric statistical test will be conducted (one-sided Kolmogorov-Smirnov) against the null hypothesis that the diversion percentage is less after the ICM deployment. A sufficiently strong observation in the opposite direction, with probability of falsely concluding the alternative at no more than five percent, will result in the conclusion that the ICM deployment did affect behavior relative to the diversion scenario.

5.3.4 Issues

Successful evaluation of the traveler response is dependent on the completeness and comprehensiveness of traveler response survey data from each site as well as the traveler information usage and network performance data.

For the surveys, it is critical that they be fielded as planned and that the detailed, clean, valid, and tabulated data be provided in a timely fashion after their completion. It is expected that certain difficulties such as low response rates or missing data may be encountered. Some specific risks associated with this evaluation include the following:

- During the pre and post-evaluation phases, there may not be incidents sufficiently major in nature to warrant route diversion/switching modes – this would limit the ability to conduct pulse surveys.
- Respondents may not be on the road during the incident identified for the pulse survey, and thus response to the pulse survey may be low
- Attrition among panel members may be high.

The Volpe Center will address these issues in their own planning and administration of the surveys to assure the resulting data optimizes the resources available for its collection.

The traveler information usage evaluation will be able to be completed in some form. However, the most desirable form of it may not be possible. The analysis calls for usage information that can differentiate corridor use from more general regional use. If this level of granularity is not available for all of the dissemination outlets (e.g., phone and web), the analysis will focus only on the systems where it appears that route-specific usage statistics may be available.

The diversion analysis for incident locations depends on the availability of traffic counts for specific time periods, the occurrence of a particular type of incident that produces an ICM response, and very specific logistical constraints regarding the diversion scenario location. Should these conditions not occur frequently enough during the pre or post-deployment periods, the evaluation will consider alternative analyses that focus on externally measurable behavior changes, such as increased use of transit resources from park & ride lot utilization.

5.4 Quantitative Analysis of the Corridor Performance – Mobility

A primary objective of the ICM evaluation is to understand ICM impacts on overall corridor performance in terms of the safe and efficient movement of travelers. Quantitative analysis of corridor mobility performance is a core component of the evaluation in that it directly measures the "bottom line" ICM objective: to provide a measurable improvement in mobility within the corridor. This analysis includes a comprehensive, before-after comparison of the impact of ICM strategies on corridor mobility performance. The key MOEs for this analysis are travel time, delay, throughput, and travel time reliability. Corridor mobility performance will be evaluated in terms of these four MOE categories at the corridor and facility levels and by mode. The analysis will also evaluate the MOEs at vehicle-based and person- or trip-based levels to capture the granularity of ICM's impacts on mobility performance.

Success of this analysis depends on factors including: 1) utilization of a comprehensive, consistent set of performance measures that are familiar and meaningful to the transportation community; 2) working closely with the sites to ensure that the data needed to test specific mobility hypotheses are collected; and 3) tracking of incidents and other exogenous factors and taking their influence into account in the analysis of corridor mobility performance.

Key challenges with significant impacts on this analysis include:

- Data granularity and availability of the roadway facilities and transit services in the corridor
- Approach to capture person- or trip-based MOEs using field-collected data, or suitability of field data for analyzing person- or trip-based MOEs
- Use of the AMS model in evaluation to overcome data gaps.

Potential impacts of those challenges and approaches to address them are discussed in the Analysis Approach section.

The evaluation team will work closely with the ICM Management Team, the AMS contractor, and the demonstration sites to determine actual performance measures and scenarios to evaluate, and collect data necessary for this analysis. Based on the results from the AMS model, it is expected that the benefits of the ICM System are mostly realized during high-demand conditions and major capacity reduction events such as major incidents. Therefore, the national evaluation will pay special attention in analyzing the corridor mobility performance during high-demand conditions and major capacity reduction events, including major incidents and unusual conditions (i.e., severe weather, holiday and seasonal congestion, homeland security events, and planning special events).

Figure 5-4 provides a summary of this analysis area and provides context for the rest of this section linking hypotheses, data sources, design, and analysis approach.

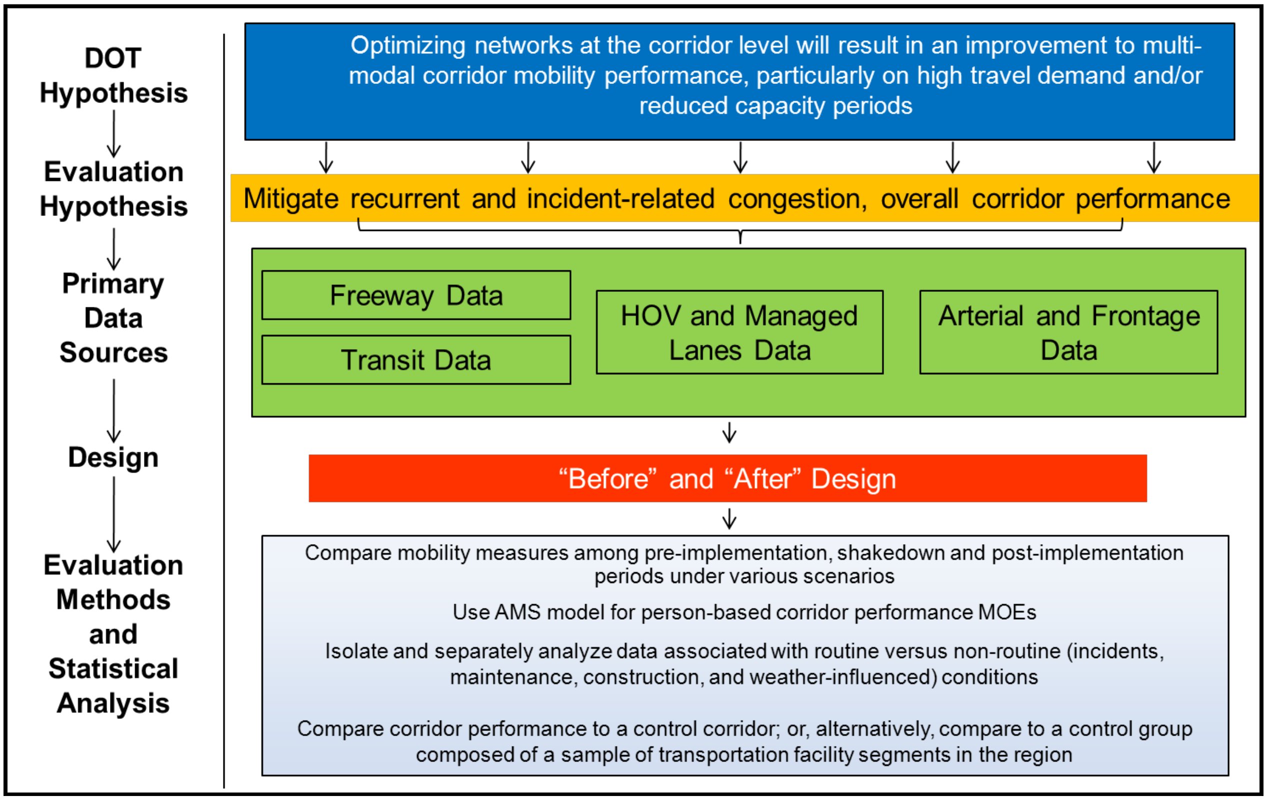

Figure 5-4. Overview of Mobility Analysis

5.4.1 Evaluation Hypotheses

As indicated in Figure 5-4, U.S. DOT has identified a single, broad hypothesis related to ICM mobility impacts:

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

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

Overall ICM Mobility Hypotheses:

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

ICM Strategy-Specific Hypotheses:

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

5.4.2 Key MOEs and Data

As reflected in the hypotheses, overall ICM deployment and specific ICM strategy mobility impacts are expected to manifest in four areas: reduced travel times, reduced delay, increased throughput and improved travel time reliability. The evaluation will assess these four types of impacts at the corridor, facility and modal level under various scenarios, including day-to-day recurring congestion during AM and PM peaks, major and minor traffic incidents, special events, congestion caused by holiday and seasonal travel, etc. Specifically:

- Travel time will be analyzed and presented as trip-weighted average time to traverse the distance needed from origin to destination by time of travel and facility type within the study corridor and by direction of travel.
- Delay will be calculated as the total observed travel time less the travel time under uncongested conditions, reported in terms of both vehicle-hours and person-hours of delay.
- Both vehicle and person throughput will be evaluated. Key throughput MOEs will include: change in corridor vehicle-miles traveled; change in corridor person-miles traveled; and change in corridor vehicle-hours traveled and person-hours traveled.
- Travel time reliability describes the predictability of travel time along the corridor. It is one of the most important indicators for corridor mobility performance as it describes consistency and dependability of travel. Travel time variability is another indicator for travel time reliability that describes how travel time varies over time and the impacts of this variance on corridor users.

Table 5-5 presents specific evaluation MOEs in each of these four impact areas. In some of the other evaluation analysis discussions in this chapter, similar tables have included the evaluation hypotheses. Those hypotheses have been omitted here to save space and avoid redundancy. Because many hypotheses include all four or several of the four mobility impact categories (travel time, delay, etc.), listing each hypothesis in Table 5-5 would make for a very long table with considerable redundant information, that is, many specific MOEs would be repeated many times. Given the approach taken here, the trace between mobility-related evaluation hypotheses and specific MOEs can be followed via the link between the MOE impact areas called out in the various mobility hypotheses (Section 5.4.1) and the appearance of those same four areas within the "MOE category" column in Table 5-5.

The key MOEs that will be used to test the evaluation hypotheses, along with data needed to capture those MOEs and data sources, are summarized in Table 5-5. All MOEs listed in Table 5-5 will be reported by mode to capture person and transit use. The following classification of travel modes will be included in the analysis:

- Auto-Non Managed Lanes
- Auto-Managed Lanes
- Transit
- Auto-Park & Ride-Transit

Table 5-5. Mobility Analysis MOEs, Data and Sources

MOE Category	MOE	Unit	Data	Data Source
Travel Time	Changes in Freeway GP Lanes Travel Time	Minutes	Speed from detectors	Freeway Detectors
	Changes in HOV Lane Travel Time	Minutes	Speed from detectors	HOV Lane Detectors
	Changes in Frontage Road and Arterial Travel Times	Minutes	Speed from detectors	Arterial Street Data Collection,
			Travel time data	
	Changes in Transit Travel Time	Minutes	Automatic Vehicle Location (AVL) data	Transit AVL
	Changes in Trip-weighted average vehicle and person travel time by mode and for corridor-wide	Minutes	Speed from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Travel time data	
			Transit data	Transit AVL and Automated Passenger Counts
			Vehicle occupancy	Vehicle Occupancy Counts, HOV Management System, Regional Travel Demand Model, AMS Model
	Change in Incident-Related Travel Time by mode and for corridor-wide	Minutes	Speed from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Travel time data	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			AVL data	Transit AVL
Delay	Changes in Total Vehicle Delay by mode and for corridor-wide	Vehicle-hours	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Measured travel times	Freeway and HOV Lane Detectors, Arterial Street Data Collection, AMS Model
	Changes in Total Person Delay by mode and for corridor-wide	Person-hours	Vehicle delay	Freeway and HOV Lane Detectors, Arterial Street Data Collection,
			Vehicle occupancy	Vehicle Occupancy Counts, HOV Management System, Regional Travel Demand Model, AMS Model
	Changes in Total Vehicle Delay – Freeway GP Lanes	Vehicle-hours	Volume from detectors	Freeway Detectors
			Measured travel times	Freeway Detectors
	Changes in Total Person Delay – Freeway GP Lanes	Person-hours	Vehicle delay	Freeway Detectors
			Vehicle occupancy	Vehicle Occupancy Counts, Regional Travel Demand Model, AMS Model
	Changes in Total Vehicle Delay – HOV Lanes	Vehicle-hours	Volume from detectors	HOV Lane Detectors
			Measured travel times	HOV Lane Detectors
	Changes in Total Person Delay – HOV Lanes	Person-hours	Vehicle delay	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Vehicle occupancy	Vehicle Occupancy Counts, HOV Management System, Automated Passenger Counts, Regional Travel Demand Model, AMS Model

Table 5-5. Mobility Analysis MOEs, Data and Sources (Continued)

MOE Category	MOE	Unit	Data	Data Source
Delay (Cont.)	Changes in Total Vehicle Delay – Arterials/Frontage Roads	Vehicle-hours	Volume from detectors	Arterial Street Data Collection
			Measured travel times	Arterial Street Data Collection,
	Changes in Total Person Delay – Arterials/Frontage Roads	Person-hours	Vehicle delay	Arterial Street Data Collection,
			Vehicle occupancy	Vehicle Occupancy Counts, Regional Travel Demand Model, AMS Model
	Changes in Delay per vehicle	Minutes/ Hours	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Total vehicle delay	Freeway and HOV Lane Detectors, Arterial Street Data Collection,
	Changes in Total Transit Passenger Delay	Person-hours	Passenger counts	Automated Passenger Counts
			AVL data	Transit AVL
			Transit schedule/adherence data	Transit System Reports/Records
	Change in Incident-Related Delay by mode and for corridor-wide	Vehicle-hours, Person-hours	Volume and speed from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Measured and modeled travel times	AMS Model
			Vehicle occupancy	Vehicle Occupancy Counts, Regional Travel Demand Model, AMS Model
			Passenger counts	Automated Passenger Counts
			AVL data	Transit AVL
			Transit schedule/adherence data	Transit System Reports/Records
Throughput	Changes in Transit ridership	Persons	Passenger counts	Automated Passenger Counts
	Changes in Vehicle Throughput – Corridor and by mode	Vehicles	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
	Changes in Person Throughput – Corridor and by mode	Persons	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Vehicle occupancy	Vehicle Occupancy Counts, Regional Travel Demand Model, AMS Model
			Transit passenger counts	Automated Passenger Counts
	Changes in Vehicle Throughput – freeway GP Lanes	Vehicles	Volume from detectors	Freeway Detectors
	Changes in Person Throughput – freeway GP Lanes	Persons	Volume from detectors	Freeway Detectors
			Vehicle occupancy	Vehicle Occupancy Counts, Regional Travel Demand Model, AMS Model
	Changes in Vehicle Throughput – HOV Lanes	Vehicles	Volume from detectors	HOV Lane Detectors

Table 5-5. Mobility Analysis MOEs, Data and Sources (Continued)

MOE Category	MOE	Unit	Data	Data Source
Throughput (Cont.)	Changes in Person Throughput – HOV Lanes	Persons	Volume from detectors	HOV Lane Detectors
			Vehicle occupancy	Vehicle Occupancy Counts, HOV Management System, Regional Travel Demand Model, AMS Model
	Changes in Vehicle Throughput – Arterials/Frontage Roads	Vehicles	Volume from detectors	Arterial Street Data Collection
	Changes in Person Throughput – Arterials/Frontage Roads	Persons	Volume from detectors	Arterial Street Data Collection
			Vehicle occupancy	Vehicle Occupancy Counts, Regional Travel Demand Model, AMS Model
	Changes in Transit Throughput	Persons	Passenger counts	Automated Passenger Counts
	Changes in Vehicle-miles traveled by mode and for corridor-wide	Vehicle-miles	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
	Changes in Person-miles traveled by mode and for corridor-wide	Person-miles	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Vehicle occupancy	Vehicle Occupancy Counts, Automated Passenger Counts, LRT Counts, Regional Travel Demand Model, AMS Model
	Changes in Vehicle hours traveled by mode and for corridor-wide	Vehicle-hours	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
	Changes in Person-hours traveled by mode and for corridor-wide	Person-hours	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Vehicle occupancy	Vehicle Occupancy Counts, Automated Passenger Counts, LRT Counts, Regional Travel Demand Model, AMS Model
	Changes in Incident-Related Throughput by mode and for corridor-wide	Vehicles, Persons	Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Volume from detectors	Freeway and HOV Lane Detectors, Arterial Street Data Collection
			Vehicle occupancy	Vehicle Occupancy Counts, Regional Travel Demand Model, AMS Model
			Transit passenger counts	Automated Passenger Counts

Table 5-5. Mobility Analysis MOEs, Data and Sources (Continued)

MOE Category	MOE	Unit	Data	Data Source
Travel Time Reliability*	Changes in Travel Time Index by mode and for corridor-wide	None	Measured travel times	Freeway and HOV Lane Detectors, Arterial Street Data Collection
	Changes in 95th percentile travel time by mode and for corridor-wide	Minutes	Measured travel times	Freeway and HOV Lane Detectors, Arterial Street Data Collection
	Changes in Standard deviation of travel time by mode and for corridor-wide	Minutes	Measured travel times	Freeway and HOV Lane Detectors, Arterial Street Data Collection,
	Changes in Planning time index by mode and for corridor-wide	None	Measured travel times	Freeway and HOV Lane Detectors, Arterial Street Data Collection,
	Changes in Buffer index by mode and for corridor-wide	Percentage	Measured travel times	Freeway and HOV Lane Detectors, Arterial Street Data Collection,
	Changes in Transit On-Time Performance	Percentage	AVL data	Transit AVL
			Transit Schedule and Adherence Data	Transit System Reports/Records

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* Definitions of travel time reliability measures are described in Section 5.4.3.

Successful and meaningful evaluation of the MOEs presented in Table 5-5 is dependent on the completeness and comprehensiveness of data from the deployers. While it appears that most of the data required for the MOEs will be available, there are some areas of uncertainty. These uncertainties, or challenges, include the following:

- **Data granularity and availability of the roadway facilities and transit services in the corridor.** Based on the information gathered to date from the demonstration sites, there may be data gaps on arterial streets, especially travel times. Although the sites expect limited to no gaps on key arterials, extent of gaps and need for sites' supplemental data collection, in particular during pre-ICM deployment data collection period, needs to be resolved in the test plans. Potential remedies offered for the sites consideration include:
  - Installation of additional sensors/detectors along key arterials to fill data gaps. However, if point-based sensors are used, there are problems with calculating arterial travel times using such data. It might be necessary to use other probe-based technology to collect additional arterial data, including travel time. It is uncertain at this point if sites plan to use other technology that can track vehicles to derive travel time on arterials or use any other means to collect arterial travel time information.
  - Use of transit AVL data on the arterials to obtain comparable travel times
  - Use of GPS trace data and traveler survey results

- **Person- or trip-based MOEs.** To accurately capture person- or trip-based MOEs from field data, it is desired to track individual person or vehicle movements. Such data collection capability is not currently present at the demonstration sites. One potential option could be GPS based travel logs if they are part of the travel survey. However, the design of the survey is still uncertain. The evaluation team's current approach to capture person- or trip-based MOEs relies on the AMS modeling capability for person and trip-based throughput and delay measures. In relying on the AMS model for evaluation, however, we are limited by the ability of the model to replicate ICM impacts.
- **Use of AMS model in evaluation to overcome data gaps.** As noted in the above, AMS model will be used to assist with evaluating person- or trip-based throughput and delays. To utilize the AMS model to assist in the evaluation of throughput under various conditions, multiple runs of simulation with different sets of data will be needed. It is uncertain to the national evaluation team to what extent the AMS model contractor will be able to provide such support to assist the evaluation. The evaluation team is aware that AMS supports to the evaluation will be documented in the companion documents on the site AMS Analysis Plans. The national evaluation will also document how and to what extent AMS results are used to assist in the evaluation.

5.4.3 Analysis Approach

The approach to mobility analysis in the national evaluation framework features a comprehensive, before-after comparison of the impact of ICMS on corridor mobility performance as reflected by various travel time, delay, throughput, and travel reliability measures. The analysis will evaluate scenarios that include typical daily conditions, reduced capacity conditions (e.g., incidents, construction), and medium-to-high demand conditions. It is expected that the ICM is most effective under high-demand and major capacity reduction scenarios (such as major incidents). The evaluation will pay particular attention to analyze ICM's impacts on mobility performance under such conditions.

The first step in the national evaluation involves checking and validating system data provided by the sites, identifying and facilitating the collection of any required supplemental data, and characterizing ICM-related mobility impacts at the corridor, facility, and modal level.

The first key mobility measure in the national evaluation is average person travel time by mode. This represents the weighted average time for a person to traverse from one point to another on a combination of different classes of roadways or using a combination of roadways and transit services. As such, travel time may be made up by a combination of travel times on arterial and freeway segments and possibly transit in-vehicle and out-of-vehicle times. Freeway travel times are typically derived using volume, speed and occupancy information collected through detection devices instrumented along the roadway. Transit travel times can be obtained directly from the AVL systems. Arterial travel times, as discussed earlier, will be derived using field data and supplemented as necessary with transit AVL data.

The evaluation team will collect detection data from demonstration sites, validate the data, and then calculate travel times by time of day, facility type, weather conditions, travel conditions (incident vs. recurring conditions), mode of travel, and direction of travel. The travel times will then be compared between pre-deployment (baseline), shakedown, and post-deployment periods to evaluate performance gains/changes that can be reasonably attributed to the implementation of the ICM strategies.

The national evaluation also will use travel time reliability measures as a means of assessing the effectiveness of the ICMS in improving corridor performance. Three key reliability measures will be analyzed: Travel Time Index, 95th percentile travel time, and Planning Time Index. The Travel Time Index is the ratio of the average peak period travel time as compared to a free-flow travel time. A Travel Time Index of 1.20 implies that a trip in the corridor during peak period conditions will on average take 20 percent longer than during free-flow conditions. 95th percentile travel time describes how much delay there will be on the heaviest travel days. It can be derived directly from field data. The Planning Time Index is the ratio of the total time needed to ensure 95 percent on-time arrival at a downstream destination compared to free-flow travel time. That is, it is computed as 95th percentile travel time divided by free-flow travel time. Higher values of the Planning Time Index imply that there is more variability in the travel time and that travelers need to include more travel time to arrive at destinations on time in the corridor.

Variance in travel time is another indicator for travel time reliability that describes how travel time varies over time and the impacts of this variance on corridor users. This measure will also be used for evaluation of travel time reliability, as this measure is easily understood by travelers. Travel time variability is expressed in terms of standard deviation of measures travel time as shown in Equation 2.

$$S^2 = \sum(\textit{Travel Time of } i^{th} \textit{ Trip} - \textit{Mean Travel Time})^2 / (n - 1) \qquad \text{(Equation 2)}$$

where s is standard deviation of travel time and n is the number of sample trips. Average standard deviation and variance of travel time will be calculated for each specific hour during high-demand and major capacity reduction conditions.

Another performance measure the national evaluation will use is delay. Delay is the total observed travel time less the travel time under free flow conditions, reported in terms of vehicle-hours or person-hours of delay. Particularly, the national evaluation will determine if the ICMS can reasonably be attributed to a reduction in the average delay related to incidents, maintenance and construction, and high-demand conditions. To derive person-hours delay, vehicle occupancy data (i.e., number of passengers in a vehicle) will be required. Transit passenger counts can be obtained directly from the automated passenger counters on board of transit vehicles. However, occupancy for personal vehicles may not be available. If vehicle occupancy data is not available, the national evaluation intends to use the average vehicle occupancy rate in the regional planning/travel demand models to fill the data gap for the analysis of person-hours delay.

The national evaluation will also use the measure of throughput to evaluate the effectiveness of the ICMS. Throughput is a measure of the number of users "served" by the transportation system. The reasons for assessing the impacts of the ICMS on throughput in addition to travel time, delay and travel time reliability is because of latent demand that potentially exists in the corridor. This latent demand may make it difficult to discern significant improvements in travel time, delay or travel time reliability from the ICM strategies. However, increases in corridor throughput would imply that the ICM strategies were effective in serving more vehicles and/or persons who previously could not have been served in the corridor because of the congestion that existed prior to the strategies being implemented.

Throughput will be measured in terms of VMT, person-miles traveled (PMT), vehicle-hours traveled (VHT), and person-hours traveled (PHT). It will be calculated using a combination of system data (volume and speed), derived data (travel time and delay), and average vehicle occupancy rate(s). Throughput will be measured for the overall corridor through the definition of screenlines that span all corridor facilities. Screenlines will be identified between pairs of locations that exist downstream of major flow discontinuities (exiting/entering traffic). Throughput will also be measured along the major facilities of the corridor to determine the extent to which available capacity is being effectively utilized. When throughput cannot be derived due to lack of sufficient data, for example lack of detectors or data collection capability on arterials, results from the AMS model will be used to fill the gaps.

Each of the above measures will be calculated to evaluate corridor performance by facility type, by mode, for the entire corridor, across different times of the day and days of the week. Travel time reliability and variability will also be calculated for both within day trips and across day trips (i.e., trips taken at the same time of travel on different days). In addition, travel time reliability and variability will be used to compare and evaluate the effectiveness of control strategies in response to capacity reducing events. This includes both short term events such as incidents, and long term events such as weather and construction. Comprehensive corridor performance for travel time reliability and throughput will be derived by combining results from component facilities. Average corridor-wide performance measures will be calculated as weighted averages by trip volume.

Exogenous factors that may influence evaluation of corridor mobility performance include significant changes in unemployment and gas prices, constructions outside of the corridor that may impact the corridor, transportation policy changes (e.g., converting HOV to HOT lanes, changes in transit fare, and changes in parking fees), and other non-ICM transportation system changes that may significantly change demand or system capacity. A key to the mobility analysis will be to collect data on exogenous factors before and after ICM deployment and adjust mobility measures as needed to control for any influence the exogenous factors may have had on corridor performance. Controlling exogenous factors to extract ICM-related impacts can be accomplished by one or a combination of the following methods: (1) utilize AMS to estimate the impact of ICM strategies in the absence of exogenous factors; (2) isolate and separately analyze data associated with routine versus non-routine (incidents, construction, and weather-influenced) conditions; and (3) utilize traveler surveys to identify the ICM and non-ICM influences on travel decisions.

5.4.4 Issues

A major challenge as well as uncertainty for this analysis is to perform a pre- and post-deployment comparison for incident scenarios. To perform a reasonable and meaningful comparison, it will be necessary to match incidents during pre-deployment period with incidents during post-deployment period that have similar if not identical characteristics. Such characteristics will include location, time, weather, magnitude, and duration of the incidents, as well as operational impacts on traffic operations. It is uncertain if such similar incidents will occur to allow for an ideal comparison.

Another uncertainty in this analysis relates to the use of AMS model. Discussions with U.S. DOT, the sites, and the AMS contractor have resulted in a consensus view of what AMS applications are appropriate, but final decisions about which AMS uses are possible given resource constraints will not be made until test plans are developed.

5.5 Quantitative Analysis of the Corridor Performance – Safety

Most of the strategies that will be implemented at the two ICM deployment sites are not likely to have a direct, measureable change in safety, especially given that the one year post-deployment time period is too short for definitive statistical analysis. However, safety is always a critical transportation issue, an issue that is closely linked with the congestion (supply-demand) issues targeted by ICM, and an issue that ICM project proponents will need to address to obtain political and public support. Certainly, even if safety benefits are not realized, it is important to determine if unanticipated adverse safety impacts occur. For example, making more detailed information available to travelers' via 511 and mobile-media outlets may have the unforeseen impact of increasing incidents and crashes due to an increase in distracted driving.

The approach for assessing the effect of ICM strategies on safety is three-pronged. First, although statistically significant changes in crash frequency or severity may not be possible to determine, the analysis will examine these data, including an examination of the geographic locations of crashes, which may be more telling than frequencies and severities. The second prong focuses on other safety indicators associated with potential ICM impacts on incident management: reduced incident duration (which would, in theory, reduce the number of secondary incidents and serves as a surrogate measure of secondary crashes) and fewer incident responder injuries or near-misses. The third prong also focuses on surrogates to actual changes in the number or severity of crashes: incident responder and travelers' perceptions of safety. Figure 5-5 provides a cross-reference linking DOT's identified hypothesis with more specific sub-hypotheses, data sources, design of the evaluation tests, and associated statistical methods. The remainder of this section elaborates upon the elements presented in Figure 5-5.

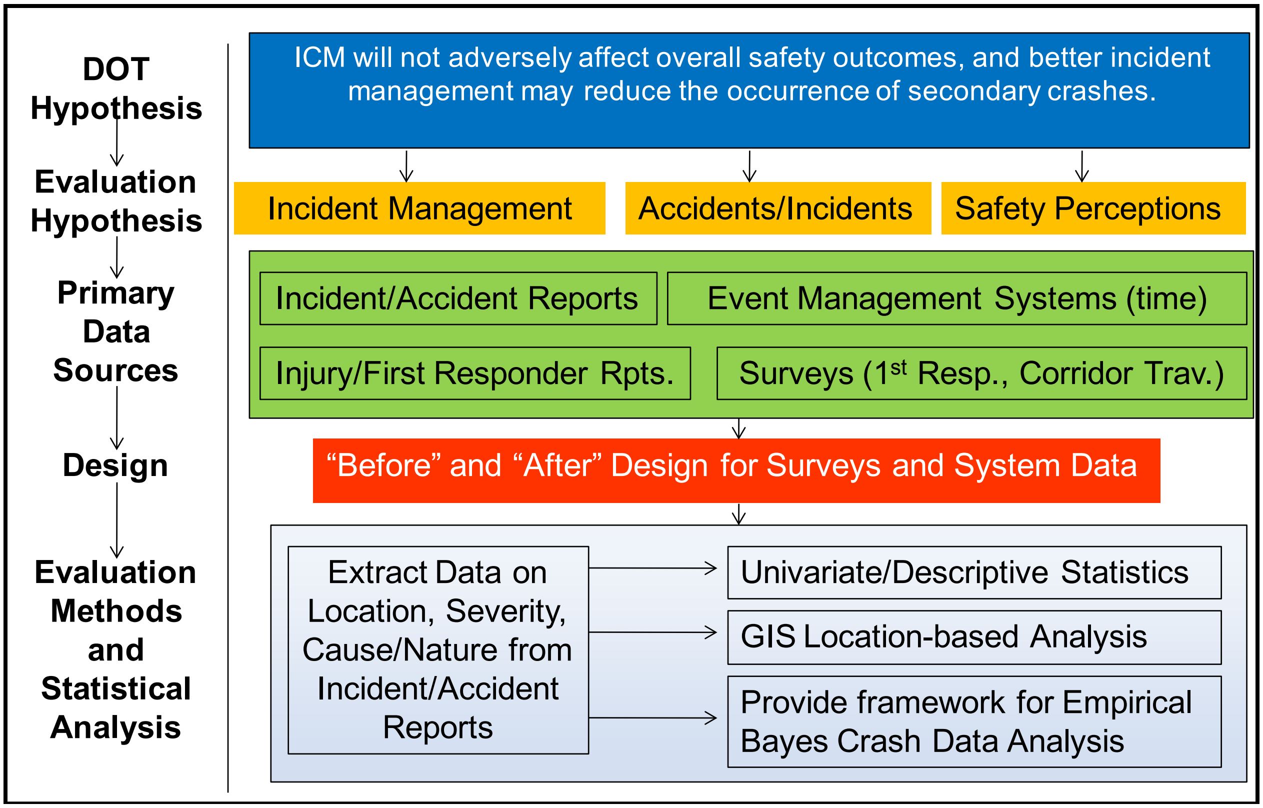

Figure 5-5. Overview of Safety Analysis

5.5.1 Evaluation Hypotheses

The DOT has blended the two elements of safety together into the following overarching hypothesis:

> *“ICM will not adversely affect overall safety outcomes and better incident management may reduce the occurrence of secondary crashes.”*

The evaluation will examine this overall hypothesis through partitioning this single hypothesis into several sub-hypotheses in the following three categories:

- Crashes/Incidents. Rates of crashes and incidents have historically been primary measures for assessing safety benefits. However, unless there are an unusually high or low number of incidents/crashes the short duration of the post-deployment evaluation period prohibits the use of traditional crash data analysis such as Empirical Bayes methods. The hypotheses in this group focus on determining if these large changes occur, but also relate more to the nature and location of incidents/crashes, which are measures that may be more sensitive in a shorter period of time than crash rates.
- Incident Management. This set of hypotheses will be used to examine the impacts of various ICM strategies on the safety aspects of incident management. Questions in this group include investigating whether the total incident duration, as defined as the corridor “return to service” time (time required to return to pre-incident or typical conditions),

changes as a result of ICM. This time measurement is one surrogate for reductions in secondary incidents/crashes and could come about through ICM-improvements to incident response (improved information sharing putting the right responder and equipment on scene more quickly) and reductions in the time required to “flush” upstream incident-related traffic queues (realized by diverting queue traffic to alternate routes or modes). This surrogate—reduced return-to-service time—is important to investigate despite being able to directly count secondary crashes (part of the crash/incident investigation described above) because many secondary crashes are not reported to or observed by local transportation or law enforcement agencies (e.g., minor fender bumps that do not impede driving capabilities). Finally, this area of hypotheses examines how faster and more effective response to incidents as well as reduced incident duration may produce a reduction in injuries/near misses for incident responders.

- Safety Perceptions. Objective hypotheses and measures of effectiveness such as measuring changes in the frequency of crashes/incidents is important and is covered in the other two groups of hypotheses. However, the perception of safety by the traveling public as well as professionals who operate in the corridor such as first responders are important measures as well. In particular, the perception that safety has not been negatively impacted by the introduction of ICM strategies is important to assess. This group of hypotheses is focused on this assessment.

5.5.2 Key MOEs and Data

Each hypothesis within the categories defined in Section 5.5.1 has been linked to one or more key measures of effectiveness and data sources. This linking is provided in Table 5-6 below.

Table 5-6. Safety Analysis Hypotheses, MOEs, Data and Sources

Hypotheses Area	Evaluation Hypotheses	Measures of Effectiveness	Data	Data Source
Incident Management	Improved information sharing (speed, quality of information and more agencies) will reduce the time until first response	Reduction in response time to incident for first responders (e.g., less exposure to secondary accidents)	Time of crash/incident; time crash/incident reported into ICM system; time first responder arrives on scene, time that the first responder is on scene, day of week, time of day	SD – Event Management Systems, Response Plan System; D – SmartNet Reports, Agency Response Records
	Reduced first response times coupled with reduced traffic queuing (resulting from improved diversions) will reduce the overall return to service time (incident duration)	Change in incident response, clearance time, and a corridor-wide return to service level (time or throughput) for similar types of incidents	Time of arrival on-scene; time incident/crash cleared, time corridor-wide return to service achieved (day of week, time of day)	SD – Event Management Systems, Response Plan System; D – SmartNet Reports, Agency Response Records
	Faster and more effective response to incidents made possible through ICM information sharing and coordination will result in a reduction in injury/close calls for first responders because their exposure to secondary incidents will be reduced	Reduction in number of injuries/close calls for first responders	Injury reports for Police, Highway Patrol, EMS, Fire related to transportation incidents/crashes (injury, cause, location, time-of-day, extenuating conditions) Time and labor hours for each incident	Agency Interviews/Logs; Agency Response Records
Crashes and Incidents	There will be a decrease or constant level of secondary incidents due to reduced congestion realized through ICM	Change in the number of secondary crashes/ crashes/incidents	Crash reports – number of secondary versus primary crash, cause of crash	SD – CHP, Police Incident Records; D – City of Dallas and other cities PD – Incident Records
	There will be no change or a decrease in the incident/crash rate in the corridor	Change in the number of crashes/incidents	Crash reports, number of incidents/crashes, geo-coded location (lat/Long)	SD – CHP, Police Incident Records; D – City of Dallas and other cities PD – Incident Records
	Increased traffic on frontage and arterial roads will not increase crashes/incidents	Change in the number of crashes/incidents	Crash reports, number of incidents/crashes, geo-coded location (lat/Long)	SD – CHP, Police Incident Records; D – City of Dallas and other cities PD – Incident Records
	By redistributing vehicle traffic, the ICM deployments will change the locations of incidents	Change in the geographic clustering of incidents/crashes	Crash reports with geo-coded locations	SD – CHP, Police Incident Records; D – City of Dallas and other cities PD – Incident Records
	Crashes/incidents will be less severe following ICM deployment due to improved travel flow	Change in the severity of crashes (rating)	Crash reports – cause of crash, indication of injury/fatality, number of individuals injured, transport to medical facility)	SD – CHP, Police Incident Records; D – City of Dallas and other cities PD – Incident Records
Safety Perceptions	Patrol operators, state patrol officers will perceive safety benefits or no increase in unsafe conditions	Change in the percent of responders	Survey data from first responders	Agency Interviews/Logs; Survey of First Responders
	Travelers will perceive improvements or no worsening of safety following ICM	Change in the percent of travelers	Responses to questions regarding perception of safety	Corridor traveler survey data

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Analysis Approach

Three separate analyses will be conducted within the larger context of Corridor Performance Safety corresponding to the three different hypothesis areas identified in Section 5.5.2. Analyses related to response management vis-à-vis corridor safety will focus on assessing the impacts on improving the overall corridor-wide return to service, reduction in secondary incidents, crashes, and close calls for first responders, and improvements in time to response. Generally, the statistical analysis will consist of using cross-classification frequency tables to examine differences in rates, frequencies, and proportions before and after ICM deployment. One important aspect to the analysis will be the measurement methodology for determining when the corridor (not the specific road segment) has reached a return-to-service level. In particular, because of the ICM strategies for diverting travelers, the corridor may reach a return to service capability long before a specific road segment does as a result of travelers using alternative transportation modes, routes, and/or shifting their time of travel. One approach will be to base this metric on person-throughput in the corridor but another possibility would be to leverage the AMS models to assist in estimating the time for a corridor-wide return to service level. The impact of extraneous factors will be examined using a case-control matching strategy if possible where incidents prior to ICM deployment are matched to incidents post-ICM deployment and analyzed as a pair. The AMS models will also be used to develop cases and controls that can be paired to observed incidents if needed. As noted in other analyses, it is assumed that AMS modeling support will be made available to the evaluation, but that will need to be further explored and finalized as test plans are developed.

A traditional statistical analysis approach for assessing safety benefits is to conduct an observational before-after evaluation of the differences in crash frequency and severity for specific project sites using the Empirical Bayes (EB) method. Application of the EB method requires a safety performance function (SPF) for a reference group of corridors similar to the two ICM corridors. Usually an existing SPF from the Highway Safety Manual or from *SafetyAnalyst*[3] can be calibrated for this purpose; however, SafetyAnalyst was primarily designed to estimate the safety benefits of physical changes to the roadway such as rumble strips and signing, and thus specific SPF for corridors that are somewhat similar to the two ICM sites will need to be developed as part of the evaluation. This development will consist of obtaining crash data reports from State DOTs for these other corridors over the same time period as the pre- and post-ICM deployment period. It is not necessary that these corridors have exactly the same characteristics as the ICM deployment corridors in Dallas and San Diego, however, the closer these corridors are to the study corridors, the more the results can be calibrated to remove impacts of exogenous factors such as national shifts in driving behavior, gasoline price elasticity, etc. This analysis may not show significant improvements in accident reductions, but a severe decrease in safety relative to other corridors would likely be identified making this analysis useful to examine.

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[3] Developed by Midwest Research Institute under contract to U.S. DOT. See Hauer, E., D. W. Harwood, F. M. Council, and M. S. Griffith, "Estimating Safety by the Empirical Bayes Method: A Tutorial," *Transportation Research Record 1784*, Transportation Research Board (2002), and www.safetyanalyst.org.

A key limitation to the analysis of safety benefits with respect to crashes and incidents is the duration of the post-deployment data collection period. Typically, three-to-four years of crash data are needed to conduct a robust crash data analysis. The one year worth of post-deployment collision data (or several months less allowing for the lag in states' crash data processing) is probably not enough to support strong conclusions unless there is a very dramatic shift in the crash/incident rates in the corridors. However, examination of this readily-available crash data may provide some useful perspective on changes in the nature and location of incidents pre- and post-ICM. In addition to the traditional before-after comparison of crash rates, statistical cluster analysis using Geographic Information Systems and geo-spatial modeling tools will be used to determine if there has been a shift in the location, severity, and/or nature of the crashes/incidents. For example, the overall corridor crash rate may not change pre- to post-ICM, but the ICM strategies may be effective in reducing the severity of crashes or eliminating persistent bottlenecks.

Finally, traveler and system operator perceptions of safety can also be informative and should be part of the safety evaluation. The evaluation recognizes that the traveler's perception of safety does not always track with actual road conditions and safety benefits. However, for travelers, sometimes the perception of safety is as important as the realization of actual changes in collision rates and assessing this level of safety is important both as an evaluation metric as well as an exogenous influence. For example, certain segments of the population typically are less-likely to leave the highway for an arterial even in heavy congestion choosing instead to "sit-it-out" due to concerns over being lost and personal safety. However, if this perception changes as a result of the ICM strategies, then there may be diversion and travel leveling that could occur even in situations where ICM strategies are not employed. For example, a person who was previously reluctant to divert from the highway learns from a friend or neighbor about how easy it is to try the alternative route and the increased information available for the alternative, they may try it and then continue to use the arterial or be more willing to try other alternatives on non-ICM corridors.

System operator perceptions, especially among first responders, are important to capture as part of the evaluation for many of the same reasons as the perceptions of travelers as these operators may have a change in the perception of safety through improvements stemming from ICM strategies. For example, tow truck operators and emergency medical services (EMS) may perceive safety improvements resulting from an increased ability to have the correct equipment (e.g., the right kind of tow truck) available or a faster lessoning of the congestion more quickly as highway traffic is diverted by an ICM strategy. Police and Highway Patrol may perceive smoother transitions for route diversion during road closures that can be traced back to ICM strategies that improve arterial signal phasing being synchronized during road closure incidents. Interviews or small discussion groups are ideal for gathering this information but surveys can also be effective and have been proposed here given resource considerations.

Statistical analyses related to the perception of safety will be conducted using the same statistical methods that are discussed in the Traveler Response analysis approach section of this document.

5.5.3 Issues

As previously discussed, the length of the post-deployment observations hinders the ability to identify all but the most radical changes in crash or incident rates. This challenge is compounded by the typical lag time between a crash and the availability of the processed crash data. These lags can run to several months, sometimes as much as six months, reducing an already compromised 12-month data set to a very-compromised 6-month data set. It will be important to research the time lag issue as test plans are developed. Also, other analyses will need to be used as surrogates for the traditional safety benefit analysis, though this approach could be instituted by the ICM local partners in future years as the follow-up period grows. The evaluation will focus on analyses related to the type, nature, severity, location, and perception of crashes and incidents rather than the actual incident or crash rates. These surrogates will be sufficient to examine the "do no harm" focus of US DOT's overarching hypothesis with respect to the safety performance of the ICM deployments.

The development of the safety performance functions for use in the Empirical Bayes analysis will require the identification of control corridors that are similar enough to the ICM deployment sites so that the models can factor out the average trends in crashes. It is not important that the control corridors be an exact match, as this is virtually impossible to identify, but have similar traveler and infrastructure characteristics. Because the control corridors are essentially used by the model to factor out general trends, differences between control corridors and the ICM corridors can be accounted for by including several control corridors in the averaging. Still, acquiring crash/incident data from several corridors not included in the ICM deployment is a non-trivial exercise so there will be a balance between the number of corridors that can be included and the resources available to the evaluation.

5.6 Air Quality

The ICM deployments are intended to accomplish a number of outcomes, which include shifting travelers from congested roadways to less congested roads and/or transit, delay or elimination of trips, and improvements to roadway capacity and performance via both enhanced incident response and improved signal coordination and timing. The United States Environmental Protection Agency (EPA) MOVES model will be used to estimate changes in motor vehicle emissions associated with these outcomes for both ICM sites. MOVES is being phased in as a replacement for the MOBILE6 model for analyses across the U.S., and represents a significant update to on-road mobile source modeling capabilities, including extensive new vehicle emission rates, test data, and functionality. In MOVES, users specify vehicle types, temporal and spatial ranges, pollutants, road types, and other parameters to produce emissions calculations on local, regional, state, or national bases.

The primary inputs to MOVES used in this analysis will include both vehicle activity (vehicle miles traveled and vehicle populations) as well as representative link speeds. The activity data used as input to MOVES will be derived from the mobility analysis, and the selection of modeled scenarios will be driven in part by the scenarios studied in that analysis. Emissions will be modeled on a before/after basis for a number of different scenarios at the project level. The approach is summarized in Figure 5-6 and discussed in more detail below.

Battelle, May 7, 2012

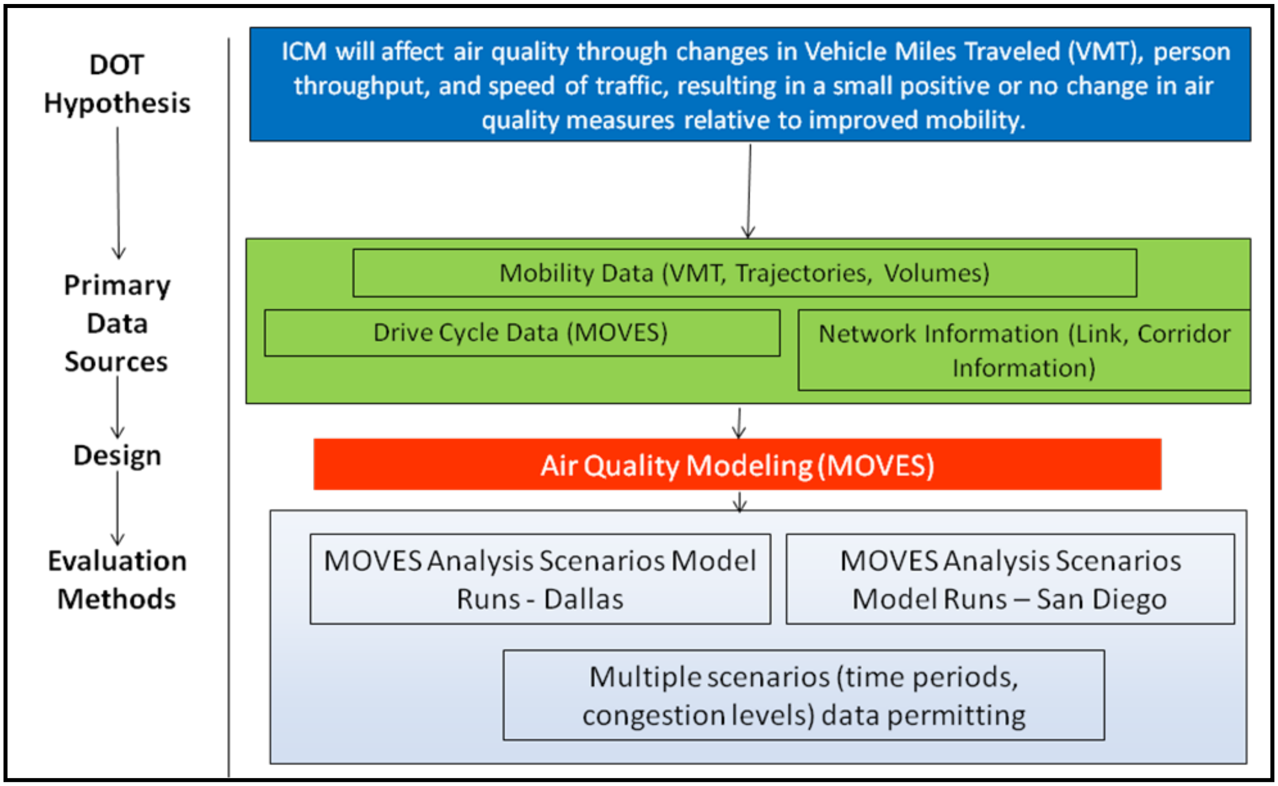

Figure 5-6. Overview of Air Quality Analysis

5.6.1 Evaluation Hypotheses

The U.S.DOT hypothesis relating to air quality analysis consists of the following statement:

> *"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."*

In many of the other evaluation analyses discussed in this chapter, the broad U.S. DOT hypotheses have been decomposed into a number of more specific hypotheses that can be individually tested. In the case of the air quality analysis, this is not necessary as the U.S. DOT hypothesis is sufficiently narrow and testable.

Changes to VMT modeled in MOVES will be dependent on vehicle activity data collected both by the sites in the field, and outputs from the AMS microsimulation model. While overall it is anticipated that VMT and vehicle populations (i.e., counts of vehicles on a per source-type basis) will be reduced throughout each corridor as a result of ICM implementation, potential changes in activity distribution across different roadway links must and will be accounted for in the air quality analysis. Similarly, anticipated improvements in roadway travel speeds and/or improved traffic flow (reflected in steadier cruising speeds with less "stop and start" acceleration, deceleration and idle) will be assessed.

It is worthwhile to note that transportation modeling performed to date (including macro-, meso- and micro-scale analyses) suggests that transportation system and traveler benefits may be positive but—at least taken over a longer period such as an entire year—can be very diffuse across time, space and individual travelers. As such, the question of whether and how much of an emissions reduction will be determined will be influenced to a significant degree by the selection of scenarios for the traffic analysis portions of the national evaluation (i.e., the Mobility Analysis). The likelihood of finding significant reductions in emissions will be higher if the traffic analysis focuses on specific travelers, roadways and/or origin-destination pairs and associated paths during specific significant traffic incidents.

5.6.2 Key MOEs and Data

The primary MOEs associated with the air quality analysis are reductions in emissions for criteria and greenhouse gases as modeled using MOVES. These MOEs can be further classified as:

- Reductions in emissions due to VMT reductions
- Reductions in emissions due to vehicle population reductions[4]
- Reductions in emissions due to decreased congestion (and associated speed profile changes)

A variety of input data is required to obtain representative model emissions from MOVES. For the purposes of this analysis, the input data needed can be classified as either *activity information* (e.g., VMT, vehicle trajectories, vehicle populations) or *fleet characterization* (e.g., age distribution, fuel parameters, vehicle inspection and maintenance programs), and are described in more detail below.

5.6.2.1 Activity Information

At the project level, MOVES allows for the definition of individual roadway links. The evaluation team will populate the link level data required by MOVES using roadway link information obtained through the site partners and the mobility analysis. Each link will be characterized by length, volume, speed and grade. In addition, vehicle fractions for each of the thirteen source types available in MOVES will be specified for each link according to collected activity data.

Since it is unlikely that probe vehicle trajectories will be available for all roadway links and scenarios of interest for the modeling analysis, the evaluation team proposes the use of AMS modeling outputs for activity inputs (both speed profiles and throughputs) to MOVES. This allows for a wider range of temporal scenarios in the air quality analysis (as opposed to use of trajectories alone) and has the advantage of "smoothing out" activity data in area where gaps, accuracy, exogenous factors and other such concerns exist. The evaluation team will work closely with U.S. DOT and staff at the University of California, Riverside (UC-R) to ensure that

[4] This could also be interpreted as reductions in vehicle throughput on a given link in the corridor. While exhaust emissions calculated in MOVES are primarily a function of VMT, start and evaporative emissions are based on vehicle population/throughput. Thus, any ICM measures undertaken that might cause vehicle throughput to change will necessarily have an effect on a portion of overall emissions, and must be accounted for.

the AMS model inputs are properly calibrated and validated. We expect that both probe trajectories and roadway sensor data will be utilized by the sites as a basis for AMS model calibration.

Although the sites' ability to support GPS vehicle data collection is still under discussion, it is anticipated that probe data will be utilized for as many key roadway links as possible given the sites' data collection resources. The specific methodologies for obtaining probe data will be more fully developed in the site-specific evaluation test plans, but may include the use of portable activity measurement systems (PAMS), or enlisting the assistance of commercial vehicle operators, many of which operate vehicles equipped with GPS instrumentation.

If roadway sensor data is used during the AMS model calibration process, the evaluation team may request the help of staff at the University of California, UC-R to assist the team with analysis of this data. In a December 2010 discussion with U.S. DOT and the evaluation team, UC-R staff agreed to provide such assistance, but as the air quality test plans are developed it will be important to formalize plans for such assistance.

5.6.2.2 Fleet Characterization

In addition to the activity data discussed above, MOVES requires additional information to describe the fleet as a whole, which will most likely remain static regardless of changes to vehicle activity in the corridor. It is expected that most of this data will be readily available from local Metropolitan Planning Organizations (MPOs) and state environmental agencies. These inputs include:

- Fuel Formulation and Supply. This includes not only specific characteristics of the gasoline and diesel fuels sold in each region, but also their market respective shares. MOVES defaults will be reviewed for applicability in each region, and if necessary, changes to inputs will be made to more accurately reflect local fuel makeup.
- Meteorology Data. Representative temperature and humidity values, on an hourly basis, will be provided as input.
- Inspection and Maintenance Programs. Specific information on county I/M programs are already included in MOVES by default. As before, these defaults will be reviewed for applicability in each region, and altered as necessary.
- Age Distribution. Under most circumstances, it is expected that the makeup of the fleet on a model-year basis will remain static for the purposes of the modeling. An appropriate age distribution will be input to MOVES.

Table 5-7 presents a summary of the inputs that are required for project-level modeling using MOVES.

Table 5-7. Air Quality Analysis Data

Data Element	Data Granularity	Obtained From	Static/Variable
Link Lengths	Miles for each link	Mobility analysis	Variable
Vehicle Trajectories	Second-by-second speed profiles (mi/hr) associated with individual links	Mobility analysis and/or AMS modeling	Variable
Average Link Speed	Mi/hr average per link	Mobility analysis and/or AMS modeling	Variable
Source Type Distributions	Source type fractions, per link	Mobility analysis and/or AMS modeling	Variable
Link Throughput	Vehicle volume, per link	Mobility analysis and/or AMS modeling	Variable
Fuel Formulation	Physical characteristics of gasoline and diesel	Local MPO or state environmental agency	Static
Fuel Market Share	Fuel fractions, area-wide	Local MPO or state environmental agency	Static
Age Distribution	Age fractions from 0-30 years, per source type, area-wide	Local MPO or state environmental agency	Static
I/M Program Data	Applied I/M factors by model year, area-wide	Local MPO or state environmental agency	Static
Meteorological Data	Hourly temperature and humidity, area-wide, by season	National Weather Service	Static

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5.6.3 Analysis Approach

As stated, the air quality analysis will center mainly on use of MOVES2010a to arrive at representative calculations of on-road mobile source emissions associated with effects of ICM implementation in both the Dallas and San Diego areas[5]. Using the vehicle activity data collected as part of the evaluation, along with other required inputs to the model, the evaluation team will calculate emissions of hydrocarbons, carbon monoxide, carbon dioxide equivalents, oxides of nitrogen, and particulate matter for vehicles in the corridor. This analysis will be performed for the regions of interest both before and after implementation of the ICM.

The evaluation team will execute MOVES at the project domain level to achieve this goal.[6] At this level, the model must be run for a single hour, day, type (weekend or weekday), month, and county. Several model runs will be executed for multiple hours and multiple seasons in MOVES

[5] The evaluation team understands that SANDAG currently uses the California EMission FACtors model (EMFAC), rather than MOVES, in its air quality evaluations, and that the inputs required to run each model differ significantly. The evaluation team will work with SANDAG to convert fleet characterization data from EMFAC to MOVES format.

[6] It has been suggested that the evaluation team should consider running MOVES at the county level using the custom domain option to represent the study areas. While we plan to investigate this methodology during test plan development, one concern we have regarding county level modeling for this analysis involves input of vehicle probe traces to MOVES. At the project level, speed traces (as well as average speeds) are explicitly provided for as a basis for the model to calculate operating mode distributions for individual links. This is not the case at the county level, where default operating distributions are used to calculate emissions. While these default operating distributions can be modified, it is a complex process and EPA does not currently encourage or provide guidance for such a methodology.

to provide an accurate picture of emissions changes associated with the ICM, in accordance with the most recent versions of EPA's "PM Hotspot Guidance"[7] and "Project Level CO Guidance".[8] As stated in the guidance, the general goal is to select, for a given scenario, morning peak, midday, evening peak, and overnight emissions for each of four calendar quarters, for both build and no-build cases. These emissions changes will be estimated for weekdays and weekends, by hour, and totaled daily and seasonally across roadway links as appropriate, to the extent that representative activity data is available for specific time periods. It is important to note here that it is not necessarily our intent to provide annual average emissions for the corridor. In fact, this may not be possible if data for all seasons of interest proves unavailable. Rather, to the extent possible, we intend to demonstrate the effects of ICM on emission across over a variety of temporal/seasonal situations. Each scenario modeled will present a before/after ICM basis, with associated air quality impacts, for a particular time period.

The evaluation team will work to ensure that scenarios that are modeled capture appropriate changes in both traffic volume and speed profiles associated with the ICM deployments, since MOVES is particularly sensitive to adjustment of these variables. In setting up these scenarios, consideration will be given to modeling significant incidents (e.g., traffic obstructions or sporting events) when possible, during which more substantial air quality impacts are expected. Such incidents may be modeled in addition to, or possibly instead of, typical daily conditions or minor incident conditions when substantial impacts are unlikely, depending on data availability.

It is anticipated that throughputs and speeds obtained from the AMS model will include all of the roadway links in each corridor. The resolution of these links should thus be sufficient to adequately describe vehicle traffic and activity patterns for the purposes of air quality modeling. However, in the event that not every individual roadway in the ICM is available from the AMS model for input to MOVES, the Battelle team will select a sufficient number of representative links to cover both the spatial variations and differences in driving activity within the corridor. Per EPA's "Hotspot Guidance", an appropriate sampling of vehicles and links "can be used to model higher volume segments by adjusting the resulting sum of emissions to account for higher traffic volume." In this way, the trajectories and volume/average speed data obtained from the field can be assigned to a smaller number of links, and the sum of the modeled emissions from these links adjusted by an appropriate factor to represent all of the emissions in the area for a given scenario.

Exogenous factors will impact the air quality analysis through their impact on the activity data that constitutes the critical MOVES input. That is, to the extent that VMT, vehicle population and vehicle operating mode data reflect both ICM and non-ICM (exogenous factor) driven changes, the influence of the exogenous factors will be passed through the air quality modeling stage and represented in the air quality results. Therefore, the approach to controlling for exogenous factors in the air quality analysis will be to utilize activity data that has, to the extent possible and as described in the Corridor Performance: Mobility Analysis, been corrected to eliminate as much exogenous factor influence as possible.

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[7] http://www.epa.gov/otaq/stateresources/transconf/policy/420b10040.pdf

[8] http://www.epa.gov/otaq/stateresources/transconf/policy/420b10041.pdf

5.6.4 Issues

Although the evaluation team is confident that the proposed approach will be sufficient to address the impacts of the ICM deployments on local air quality, there a couple issues to keep in mind during the analysis and which will be considered as test plans are developed.

First, as discussed earlier, the primary approach to characterizing vehicle operating mode distributions is to utilize observed vehicle trajectory data. One of the reasons a fall-back approach is necessary is because it can be challenging to predict the timing and location of relatively infrequent, severe traffic incidents (where the greatest air quality impacts are expected), and thus it may be difficult to collect vehicle probe driving schedule data for them. Historic data on incident frequency, severity and location will be utilized in an attempt to identify, in advance, times and locations where incident conditions are more likely to occur. This may allow scheduling on very short notice of vehicle probe data collection (congestion chasing). If, despite these efforts, it is not possible to collect trajectory data, the secondary approach, using average link speed, will be utilized.

The second issue is also related to the question of the source of trajectory data. Care will need to be taken in comparing before/after results for a given ICM scenario to consider whether the different before and after ICM MOVES runs utilized different sources for trajectory data.

Finally, devising MOVES model runs that capture a wide range of possible scenarios will prove crucial to characterizing air quality as a whole.

5.7 Benefit-Cost

The BCA is largely derivative in that it relies on the output of other evaluation tasks (e.g., safety, air quality, mobility) to quantify the effects of ICM deployment. ICM strategies generate outcomes that can be monetized and fed into the benefit-cost analysis (BCA). ICM strategies, including adding transit capacity and en-route traveler information systems, will collectively serve to generate economic benefits through travel time savings, enhanced travel time reliability, reduced motor fuel costs, fewer emissions, and reductions in the number and severity of crashes. This section outlines the methods that will be used to translate these ICM strategies into monetized benefits and compare them to the costs of ICM deployment.

It is recognized that a standard, U.S. DOT-endorsed approach to travel time reliability in benefit-cost analysis has not emerged but these benefits have been included in some recent analyses, including the AMS Phase 2 work. The proposed approach to travel time reliability is presented here with the understanding that the approach may be adjusted during the development of the BCA test plans.

An integral part of the business case for ICM is an examination of the benefits and costs associated with system deployment. An overview of the BCA approach is presented in Figure 5-7. The BCA is designed to test the hypothesis that ICM delivers benefits that exceed the costs of implementation and operation. Figure 5-7 identifies the primary data sources and evaluation methods proposed for the BCA, and notes that the analysis will include a “with” and “without ICM” component to ensure that the marginal impact of ICM technologies are evaluated over a 10-year analysis time horizon. The BCA data sources, design, and evaluation methods are explored in more detail in the remainder of this section.

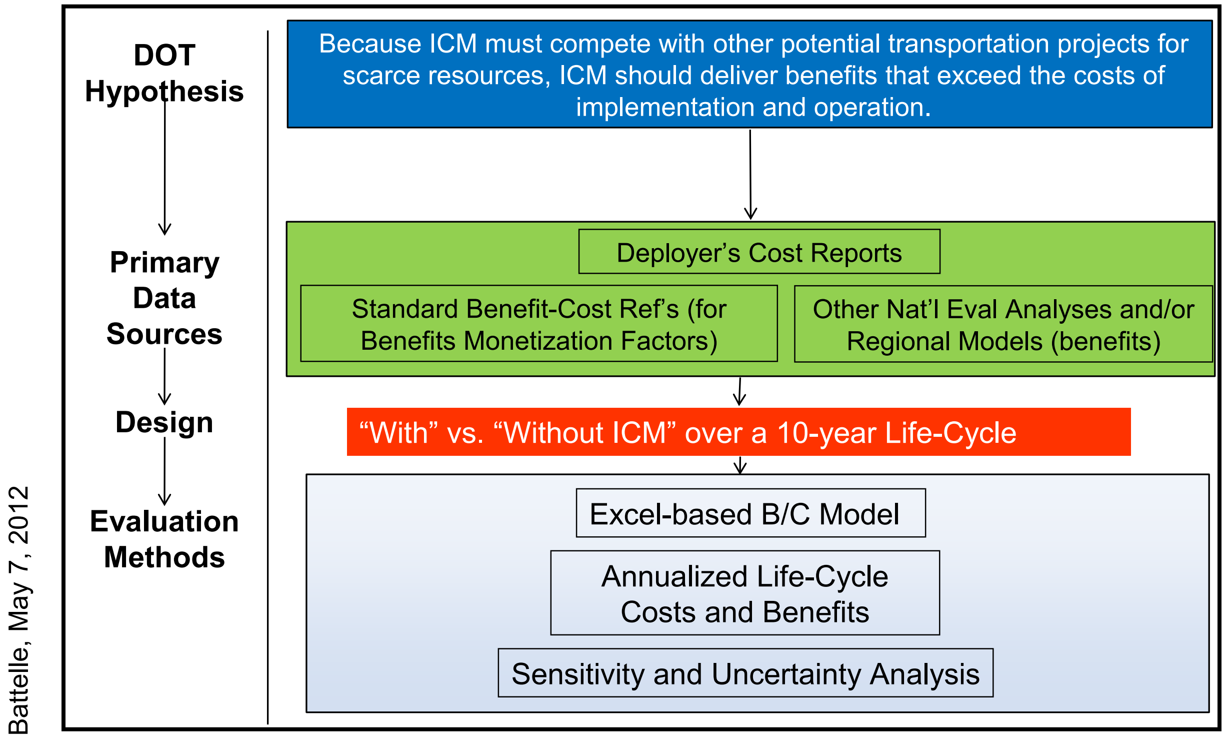

Figure 5-7. Overview of Benefit-Cost Analysis

The examination of a broad spectrum of benefit and cost elements is considered a key objective of the benefit-cost analysis. Figure 5-8 depicts the major benefit and cost elements, and illustrates the general methods used to combine these factors to yield benefit-cost ratios (BCRs). The procedures and data used to support this analysis are detailed later in this section.

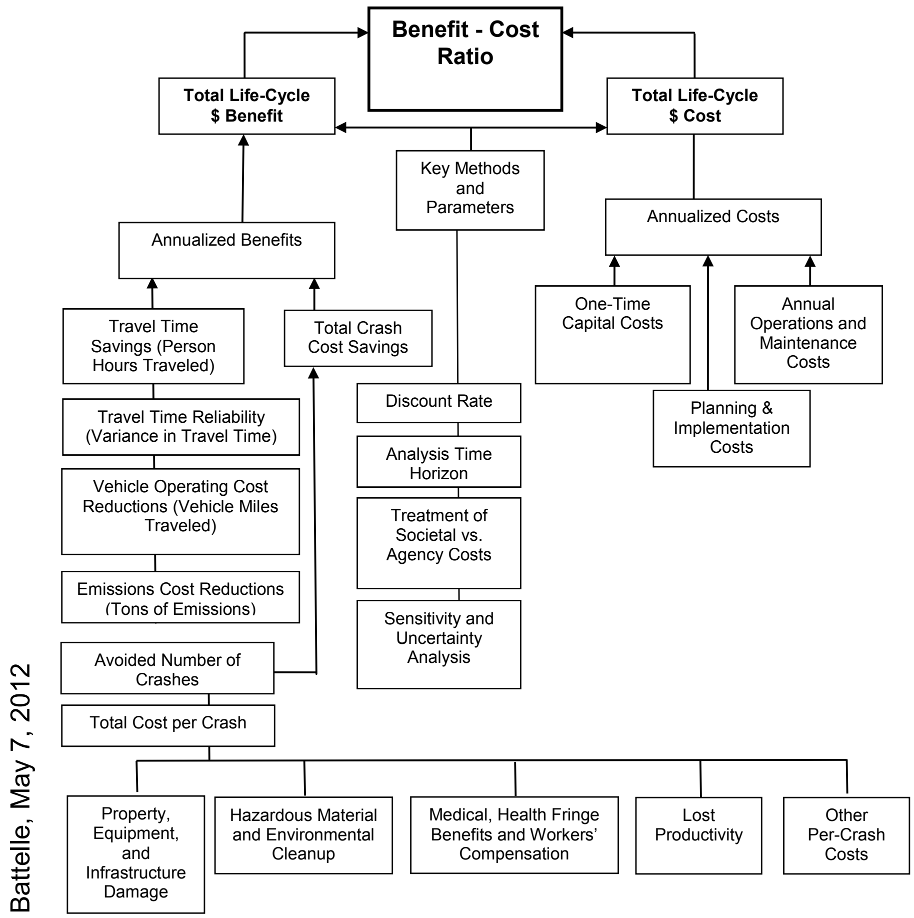

Figure 5-8. Framework for Estimating ICM Benefits and Costs

Because ICM must compete with other potential transportation projects for scarce resources, ICM should deliver benefits that exceed the costs of implementation and operation. More specifically, the hypothesis being tested in this analysis is that present value benefits of ICM deployment will exceed present value costs over the study time horizon.

5.7.1 Key MOEs and Data

The lone key MOE for the BCA is that ICM strategies will generate present value benefits that exceed costs. This MOE will be determined by constructing BCRs for specific ICM strategies at each site included in the evaluation, as measured by dividing present value benefits by present value costs, and by calculating net benefits (benefits-costs) for each strategy, as feasible.

Expected types of ICM outcomes (documented through the other evaluation analyses) that, if identified, will be monetized in the BCA include (evaluation analysis source identified in parentheses):

- Change in travel times (mobility)
- Change in travel time reliability (mobility)

- Change in number and severity of crashes (safety)
- Change in travel time delay (mobility)
- Change in emissions levels (air quality)
- Change in transit ridership (mobility)

The BCA will rely on three other sources of data in addition to the quantified ICM outcomes from the other evaluation analyses:

- The evaluation team will collect ICM-related cost data from state and local agencies responsible for capital expenditures and operations and maintenance of ICM equipment.
- Literature and cost models will be used to monetize benefit elements.
- Data will also be collected from regional and AMS models for use in forecasting forward the effects of ICM technologies.

Table 5-8 presents an overview of the primary benefit and cost categories considered in this analysis, specific data elements, and the source(s) of data required to estimate each element. The remainder of this section describes the approaches for estimating benefits and costs of ICM deployment.

Table 5-8. Values Assigned to ICM Benefit Elements

Benefit/Cost Category	Data Element	Source of Data
Travel time savings	Reductions in travel times.	Mobility analysis.
	Travel costs for freight transportation.	FHWA-reported values, American Trucking Association, or Federal Motor Carrier Safety Administration data.
	Personal travel time values.	U.S. DOT-reported values or site-specific AMS-reported values.
Crash cost savings	Crash reductions.	Safety analysis.
	Crash costs	Zaloshnja et al. 2006, Blincoe et al. 2002, or U.S. DOT guidance.
Fuel cost savings	Reductions in fuel consumption.	Mobility analysis.
	Fuel costs.	United States Department of Energy, Energy Information Administration-reported values.
Improved travel time reliability	Travel times and standard deviation in travel times.	Mobility analysis.
Air quality improvements	Improvement in air quality.	Air quality analysis
Travel cost changes due to mode shift	Mode shifts.	Traveler response analysis.
	Motor vehicle operating costs.	AAA-reported operating cost estimates.
	Transit fares.	Transit agencies operating in corridors in which ICM is deployed.
Capital costs	Capital costs of ICM technologies.	Dallas and San Diego ICM deployers.
Operations and maintenance (O&M) costs	O&M costs of ICM technologies.	Dallas and San Diego ICM deployers.
End of life costs	End of life costs of ICM technologies, including removal and disposal costs.	Dallas and San Diego ICM deployers.

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Each benefit and cost element will be monetized with data fed into a benefit-cost model. The approaches used in estimating these benefit and cost elements, including data requirements, are discussed in greater detail in the analysis approach section.

5.7.2 Analysis Approach

The benefit-cost methodology will demonstrate how the various data collected to support this evaluation will be combined to determine the relevant BCRs. The evaluation team will work with input from the ICM deployers to estimate an economic life for each technology under investigation, as well as the ongoing maintenance costs. The economic lives of the technologies deployed in ICM will determine the BCA time horizon. A common corridor management BCA analysis time horizon is 10 years, which would include the first year after implementation of corridor management projects and a period up to 10 years following project implementation. The research team will also work with the U.S. DOT to select an appropriate discount rate for compressing annual benefit and cost values to net present value terms, though OMB Circular A-94 recommends using a 7 percent real discount rate as a proxy for the after tax rate of return to private capital.

Analysis of the various benefit and cost parameters will, when feasible, be conducted for any strategy or scenario established for this evaluation and presented in a series of tables designed to easily identify relevant BCRs. The reasons for both positive and negative BCRs will be explored and sensitivity analysis will be conducted to determine the sensitivity of the results with respect to changes in the assumptions or key parameters underpinning the analysis.

In conducting the BCA, the research team will construct with and without ICM scenarios to determine the marginal impact of ICM technology deployment on the benefit and cost elements examined in the BCA. These elements form the foundation of the BCA. The remainder of this section presents an overview of the approach for examining these benefit and cost elements.

5.7.2.1 Analysis of Benefit Elements

The basic procedure for calculating net benefits is to monetize the benefits experienced by facility users and then subtract the costs associated with ICM deployment. Table 5-9 presents the values being considered for monetizing various benefit elements. These values will be normalized to a consistent base year value for the analysis. In each case, a final determination will be made regarding which value to use during the development of the evaluation test plans. At this stage of methodology development, the evaluation team has left some flexibility in the study design. A more detailed discussion of each benefit element follows Table 5-9.

Table 5-9. Values Assigned to ICM Benefit Elements

Benefit Element	Monetized Value (to be normalized to analysis base year)
Travel Time Savings	Freight – Productivity losses based on FMCSA or ATA data, or alternatively estimated at $23.15 per hour based on FHWA-reported truck driver salaries. Personal Travel – DOT reported value of $14.32 or AMS-reported Dallas value of $16.01 and San Diego value of $24.
Crash Cost Savings	Based on values reported in Zaloshnja et al. 2006, Blincoe et al. 2002, or U.S. DOT guidance; human life valued at $6.2 million.
Fuel Cost Savings	San Diego – $3.14 per gallon for gasoline, $3.16 per gallon for diesel. Dallas – $2.69 per gallon for gasoline, $2.94 per gallon for diesel.
Air Quality Reductions	Values derived from EPA MOVES model.
Vehicle Operating Costs	AAA-reported value of 16.74 cents per mile.

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The major benefit components will be calculated using the following procedures:

- **Travel time savings.** Cost savings associated with reductions in travel time (as measured in the mobility analysis), which are a result of the improvement in traffic conditions from reduced recurring congestion experienced by motor carriers, motorists, and transit users will be calculated as described below.
  - For freight transportation, the travel cost savings depend on the opportunity cost of lost productivity associated with congestion. The value of lost productivity can be derived through operations data reported by motor carriers to the American Trucking Association or the Federal Motor Carrier Safety Administration. Alternatively, FHWA reported values of $18.10 per hour ($23.15 in 2011 dollars) based on truck driver salaries could also be used.
  - For personal travel, the travel cost savings depend on the travel time saved and the recommended U.S. DOT travel time value of $14.32 ($11.20 estimated in 2000 adjusted for inflation) per person per hour or consideration could be given to use of more site-specific values ($16.01 per hour for Dallas, $24 per hour for San Diego). Travel time savings will be estimated using facility-, trip-, and person-based travel times. Shifts in mode choice will be measured in the traveler response analysis with changes in travel time by mode assessed in the mobility analysis using site specific data. Trip- or person-based travel times will be estimated in the mobility analysis using AMS. Travel time savings can also be segmented into different delay types being avoided, as detailed in Table 5-7. Incident-related travel time delay avoided due to ICM deployment will not be additive but rather, will be treated as a component of the overall travel time savings.
- **Crash cost savings.** The reduction in the number of incidents by incident type (as measured in the safety analysis) determines crash cost savings. Crashes result in property damage, lost productivity (e.g., crash investigation, lost wages, recruitment and training replacement workers), medical costs, travel delay, legal and court costs, emergency services, insurance costs, and other costs to employers. The costs associated with crashes are differentiated based on crash severity, ranging from no injury to fatality. The report entitled *Revised Costs of Large Truck- and Bus-Involved Crashes*, prepared by the Pacific Research Institute for the Federal Motor Carrier Safety Administration, documents the costs associated with large truck- and bus-involved crashes and provides perhaps the best single source for estimating the comprehensive costs of truck and bus crashes.[9] The report entitled *Economic Cost of Motor Vehicle Crashes* constitutes one of the major sources of crash cost information in the U.S. for basic vehicles.[10] The values presented in the aforementioned reports could be used to monetize crash costs. These costs could also be estimated using guidance provided for the National Highway Traffic Safety Administration: http: http://ostpxweb.dot.gov/policy/reports/VSL%20Guidance%20031809%20a.pdf. This

[9] Zaloshnja, Edward and Ted Miller (Pacific Institute for Research and Evaluation), "Revised Costs of Large Truck- and Bus-Involved Crashes," prepared for FMCSA, 2006.

[10] Blincoe, L. et al., (NHTSA) "The Economic Cost of Motor Vehicle Crashes, 2000." May 2002

guidance estimates the value of a statistical life at $6 million in 2009 dollars, and provides factors for reducing crash costs based on the injury severity.

- **Fuel cost savings.** The computation of fuel cost depends on fuel prices in the local area, fuel efficiencies under various driving speeds, and miles traveled. Data from the mobility analysis will be used to determine fuel savings. Motor fuel prices will be obtained from the U.S. Department of Energy's Energy Information Administration at *http://tonto.ei*a.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm, and these values will be used to monetize the costs of wasted fuel. In 2010, the average prices of gasoline in California and Texas were $3.14 and $2.69 per gallon, respectively. Diesel costs were estimated by EIA at $3.16 per gallon for California in 2010 and $2.94 per gallon for Gulf Coast states in 2010.
- **Improvement in travel time reliability.** The benefits realized from improved travel time reliability depends on travel time value and the standard deviation in travel time (as measured in the mobility analysis). Monetizing reliability is still an emerging science with the valuation of reliability sensitive to location, purpose of travel, and time of travel. The valuation of reliability will be further defined in the site-specific benefit-cost analysis test plans based on discussions with the sites and USDOT.
- **Improvement in air quality.** The EPA MOVES model will be used in both Dallas and San Diego to calculate emissions rates and costs.
- **Changes in travel costs for those who shift from auto travel to public transit.** These benefits reflect the difference in travel cost between driving and taking public transit. The computation of driving cost will be based on vehicle operating costs, while the cost of taking public transit will be tied to the fares paid by those who shift to transit the travel cost savings or losses due to the mode shift. Those calculations will be based on mode shift data from the Traveler Response and/or Mobility Analyses. Operating costs will be monetized using AAA- reported value of 16.74 cents per mile. In addition, the benefits from more travelers taking transit (and thus not congesting the roads) will be calculated as part of the travel time savings benefits.

These and other benefit elements identified while conducting the ICM evaluation will be summed and discounted into a lump-sum present value estimate of benefits.

5.7.2.2 Analysis of Cost Elements

The research team will prepare a cost reporting scheme with detailed cost categories by type of project and reporting entity. The costs to be considered in the BCA will only include those annual expenditures occurring within the study time period that can be attributed directly to ICM. For instance, if a transit agency operating in a studied corridor currently operates a bus fleet within the corridor with an annual operating budget of $1 million and under investments carried out as part of ICM expanded the operating budget of the bus fleet to $1.5 million, only the expanded budget of $0.5 million would be reported. Note that the study time frame will be set to account for the full life cycle cost of each technology. To the extent that a technology's useful life extends beyond the 10-year time horizon, the research team will estimate the salvage value of the equipment using the methodology outlined at http://www.dot.state.mn.us/planning/program/benefitcost.html.

Cost data will be obtained from the Dallas and San Diego ICM deployers. Data will include the capital costs associated with the various projects undertaken as part of the ICM strategy, operation and maintenance costs, replacement costs during the analysis time horizon, and end of life costs. Illustrative cost categories for the US-75 Integrated Corridor in Dallas, Texas are highlighted below:

- Capital investment costs.
    - Transit purchases, including mobile data terminals, radio systems, and business systems
    - Purchase and deployment of arterial DMS, cameras, and ramp meters
    - Upgrade of ATMS and traffic signal controllers
- Operations and Maintenance Costs
    - Operation and maintenance costs associated with expanded transit equipment
    - Operation and maintenance costs of arterial DMS and ATMS
- Replacement costs for ICM equipment and infrastructure, including arterial DMS, ATMS, mobile data terminals, and radio systems
- End of life costs, including removal and disposal costs.

To the extent feasible, cost reporting will include full agency costs. The research team will work with the San Diego and Dallas deployers to determine the agency costs that extend beyond the purchasing, installation, and operations and maintenance of ICM technologies. These administrative cost categories, including planning and training costs, may be difficult to isolate and quantify.

ICM systems do not operate in isolation and, in fact, build on existing traffic management, transit, and other ITS systems. Thus, the BCRs generated from this BCA cannot be applied at other sites without more knowledge of asset requirements and existing on-site systems. From the standpoint of this BCA, former investments in ICM-enabling systems will be considered sunk costs and the focus of our analysis, in turn, will be on the marginal benefits and costs associated with new ICM investments.

5.7.2.3 *Forecasting Benefits over a 10-Year Time Horizon*

The BCA envisioned for this study is not static inasmuch as benefits and costs are measured over an extended time horizon. Because the comparison is with and without ICM technologies, the research team must forecast impacts resulting from ICM deployment. When considering forecasting tools, they must have the capacity to extend trends currently underway and include the impacts of other planned transportation projects over the analysis time horizon in order to determine how ICM technologies may change current forecasts. To that end, the research team considered using either local regional models or the AMS models already developed for these corridors to extend the benefit factors outlined previously (e.g., time savings, crash reductions, emissions reductions) over ten years. After further discussion with the ICM deployers and US DOT, it was determined that using the regional or AMS models to forecast benefits over a

10-year time horizon would be speculative and could introduce uncertainty into the estimation process. Thus, the determination was made to fall back to the position that benefits experienced in the year following ICM deployment would continue throughout the 10-year analysis time horizon.

5.7.2.4 Economic Model

Battelle will develop a detailed benefit-cost model for ICM. The model will be designed to enable the user to change general study parameters – including those related to crash-reduction rates, ICM strategies and cost elements, mobility impacts – and view the output of the model on a single worksheet. Due to its combined input/output page and embedded notes, the BCA spreadsheet-based model, once completed, could be operated without viewing study data or possessing any specific foreknowledge of the model's design.

5.7.2.5 Treatment of Risk Uncertainty

After completing an assessment of the various benefit and cost elements, the research team will conduct sensitivity and uncertainty analysis, including varying assumptions relating to: discount rates, motor fuel prices, vehicle crash rates, and emissions prices. The risk/uncertainty analysis will be designed to determine the sensitivity of BCA results to small changes in key variables. The economic model developed by Battelle will allow for easy "what if" adjustments to various inputs and assumptions.

5.7.3 Issues

There are a number of data gaps or issues that will need to be addressed in completing the BCA, as outlined below:

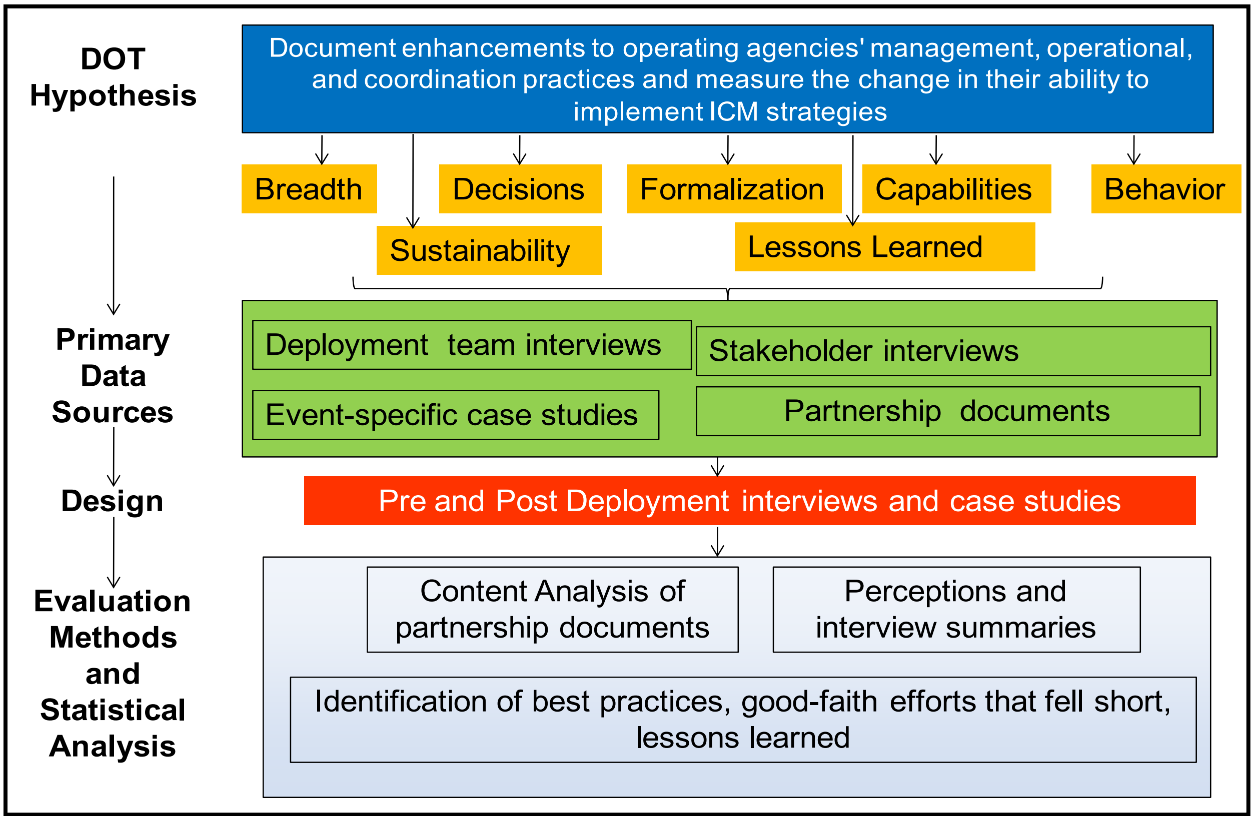
- Treatment of Specific ICM Technologies. The estimation of travel time, safety, and other ICM-related benefits will be computed through before-after analysis and, therefore, it may be difficult or infeasible to tie benefits directly to specific ICM technologies. The need to segment benefits will be considered while developing other test plans.
- Forecasting benefits over a 10-year time horizon. This issue was addressed previously in this section.
- Due to overlapping technologies and enabling systems, there are risks embedded in the data collection process, including inconsistencies, duplication, delays, and the inability to separate out ICM costs from other project costs.

5.8 Institutional and Organizational

Institutional/organizational conditions are especially important given the "silo bursting" aspects of ICM, which coordinates previously uncoordinated activities and where coordination extends well beyond written agreements to deeply permeate day-to-day operations. Change in practices require strong leadership; clear agreements, change management, new standard operating practices, training, outreach and buy-in are crucial. Within this context, the analysis will:

1. Document enhancements in ICM agency practices (including good faith efforts that fell short);
2. Measure changes in their ability to carry out strategies;
3. Document institutional issues; and
4. Generate findings that will support ICM Program Knowledge and Technology Transfer materials.

Figure 5-9 provides a summary of this analysis area and provides context for the rest of this section linking hypotheses, data sources, design, and statistical analysis methods.



Battelle, May 7, 2012

Figure 5-9. Overview of Institutional and Organizational Analysis

5.8.1 Evaluation Hypotheses

U.S. DOT did not identify hypotheses for this analysis but rather specified that the evaluation focus on documentation of enhancements to operating agencies' management, operational, and coordination practices and measure the change in the ability to implement ICM strategies. Using that guidance, evaluation hypotheses in the following areas were developed:

- **Increase in breadth of partnerships** – ICM is expected to bring new partners in a more effective manner to manage the corridor thereby enabling new lines of communication and information exchanges and a shared vision for the corridor.

- **Improved decision making** – New institutional and operational arrangements will result in more effective decision-making for the entire corridor as opposed to modal approaches.
- **Increased formalization** – While much of the current operations are at an ad-hoc level, implementation of ICM will result in more formal agreements and operating strategies.
- **New and improved capabilities** – New capabilities to manage the corridor will emerge as part of the ICM effort and investments.
- **Enhanced sustainability** – ICM will result in sustainable changes to management, operational and coordination approaches both in the short-term (demonstration phase) and the long-term, including how funding, policies, personnel, and operations and maintenance (O&M) are organized.
- **Changes in institutional behavior** – Partners in the corridor will change behavior to a joint operating philosophy with better conflict resolution and a joint vision and performance assessment of the corridor. This area includes understanding if and how agencies accept sub-optimal performance of a modal system for the greater overall performance of the corridor.
- **Lessons learned** – The ICM project will generate useful lessons learned for future ICM deployments around the country.

5.8.2 Key MOEs and Data

Specific hypothesis and MOEs have been developed within the categories described above and linked to data and data sources, as shown in Table 5-10.

Table 5-10. Institutional and Organizational Analysis Hypotheses, MOEs, Data and Sources

Hypothesis Area	Specific Evaluation Hypotheses	Measure of Effectiveness	Unit	Data	Data Source
Breadth of partnerships	Breadth of partnerships will increase over the course of the ICM project	Change in the number and level of new agreements in the region	Number and rating across stages of development (Establishing, Functioning, Maturing, Sustaining)	Interview summaries, partnership documents	Pre- and post-deployment interviews, content analysis
		Percentage of "total" and "active" agencies participating in ICM	Percentage	Interview summaries, partnership documents	Pre- and post-deployment interviews, content analysis
	DOT and the local deployment agencies will find new arrangements to be effective and to be implemented appropriately	Changes in Perceptions of deployment agencies on efficacy and satisfaction of arrangements	Rating	Interview summaries, partnership documents	Pre- and post-deployment interviews, content analysis
		Changes in Perceptions of USDOT on the efficacy and satisfaction of arrangements	Rating	Interview summaries, partnership documents	Pre- and post-deployment interviews, content analysis
Improved Decision making	Joint decision-making will improve in the corridor	Changes in decision-making roles and responsibilities	Number and rating across stages of development (Establishing, Functioning, Maturing, Sustaining)	Interview summaries, partnership documents	Pre- and post-deployment interviews, content analysis
		Change in number of communications between transportation partners	Number and rating	Tracking through ICMS logs	ICM data logs of communications
	Individual agencies' level of comfort in decision-making will increase	Perceptions of level of comfort in the capacity to use ICM during complex situations	Rating	Interview summary	Post-deployment interviews
	Resource allocation across the corridor will improve as a result of ICM	Perceptions and comfort level with inter-agency device control and sharing	Rating	Interview summary	Post-deployment interviews
		Reduction in the Percentage of time spent on routine issues	Percentage	Operator logs, interview summaries	ICM data logs, pre-and post-deployment interviews
	Conflicts in corridor management strategies will be reduced	Changes in conflict identification, logging, and resolution approaches	NA	Interview summary	Post-deployment interviews ICM Data Logs

Table 5-10. Institutional and Organizational Analysis Hypotheses, MOEs, Data and Sources (Continued)

Hypothesis Area	Specific Evaluation Hypotheses	Measure of Effectiveness	Unit	Data	Data Source
Degree of Formalization	A shared vision for the corridor will be adopted by the partners	Development of a regionally agreed upon shared vision	NA	Interview summary	Post-deployment interviews
	New Management Structures will be developed for ICM	Changes in organization and institutional structures	Number and rating across stages of development (Establishing, Functioning, Maturing, Sustaining)	Interview summaries, partnership documents	Pre- and post-deployment interviews, content analysis
	ICM will result in pre-defined and approved coordinated response plans	Number of predefined strategies for coordinated action	Number	Pre-defined strategy list	Situational awareness data from the Mobility Analysis
New and improved capabilities	ICM will result in new capabilities to monitor, control and report at each agency	Changes in the situational awareness capabilities of partner agencies	NA	Results from the Mobility Analysis	Situational awareness data from the Mobility Analysis
	The ICM demonstration will be consistent with the expectations of the agencies	Changes in agency perceptions of the ICM over the demonstration phase	Rating	Interview summaries	Post-deployment interviews
	Systems and technologies developed for ICM will be used by agencies in day to day operations	Level of Agency acceptance and use of ICMS	Rating	Interview summaries	Post-deployment interviews
	ICM Systems will be viewed as reliable and value-added by agencies	Reliability and value assessment of ICMS and other tools	Rating	Interview summaries	Post-deployment interviews

Table 5-10. Institutional and Organizational Analysis Hypotheses, MOEs, Data and Sources (Continued)

Hypothesis Area	Specific Evaluation Hypotheses	Measure of Effectiveness	Unit	Data	Data Source
Enhanced Sustainability	ICM will be viewed as sustainable from a funding standpoint	Diversity and stability of funding beyond the demonstration phase for ICM	NA	Agency self-assessment of sustainability	Post-Deployment interviews
	Organizational structures set-up for the ICM demonstration will be sustained	Incorporation of organizational structures and personnel requirements into agency budgets	NA	Agency self-assessment of sustainability	Post-deployment interviews
	O&M practices of individual agencies will change to accommodate corridor performance sustainability	Changes in O&M Practices to focus on corridor-critical resources	NA	Agency self-assessment of sustainability	Post-deployment interviews
Changes in Institutional Behavior	Agencies will accept sub-optimal modal performance when necessary for overall corridor performance	Changes in performance assessment approaches reported by partner agencies	NA	Interview Summaries	Post-deployment Interviews
	Agencies will increase the nature and the level of communications in the corridor	Increase in the number and nature of communications between transportation partners for daily operations	Number and rating	Tracking through ICMS logs	ICM data logs of communications
Lessons Learned	The ICM project will generate useful lessons learned for knowledge and tech transfer activities to other ICM deployments around the country	Incorporation of lessons learned into knowledge and tech transfer activities	NA	Site observations, interview analysis, content analysis	Pre- and post-deployment Interviews, event-specific case studies, and workshops

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5.8.3 Analysis Approach

The analysis leverages and enhances the model used for the Urban Partnership Agreements/Congestion Reduction Demonstration (UPA/CRD) evaluation featuring pre- and post-deployment stakeholder interviews, facilitated workshops, content analysis of partnership documents, and the use of event-specific case studies. As Table 5-10 shows, the bulk of the data collection is expected from pre- and post-deployment interviews with the deployment teams, reviewing the content of the partnership agreements, specific case-studies, and results from the situational awareness analysis. The following paragraphs provide some details on the data collection and the analysis approach for evaluating the hypotheses in Table 5-10.

5.8.3.1 Pre- and Post-Deployment Interviews

Interviews will be conducted with the deployment team (primarily the main project partners at both the sites) and other stakeholders (other agencies who are part of the ICM effort) by Battelle as part of the evaluation.

5.8.3.1.1 List of Interviewees

The list of interviewees will be determined in the test plans but three levels of agency personnel are going to be involved.

1. Agency Decision-Makers – These include decision-makers in terms of agency budgets and other resources at each of the partner agencies. Interviews will focus on the sustainability of ICMS, the partnerships and the degree of formalization due to the demonstration. The objective of the interviews is to assess how the decision-makers in the region view the demonstration and their support for such efforts.
2. Personnel/groups directly involved in the ICM demonstration – This group represents the personnel who have been active in the planning and the operation of the ICMS including project partners, operating staff, and the U.S.DOT. Interviews in this group will ascertain the effectiveness of arrangements, the improvements in capabilities and decision-making, and the changes in behavior and roles and responsibilities.
3. Personnel/groups indirectly impacted by ICM – The third group is important for seeing the spill-over effects of ICMS on other groups such as maintenance, traffic engineering, construction, and their perceptions of ICMS.

5.8.3.1.2 Interview Structure and Approach

These interviews will be conducted once in the pre-deployment phase and at least two times in the post-deployment phase. Ideally, these would be one-on-one interviews or in some cases, small group interviews. Large meetings are not suggested due to the difficultly in scheduling them but also due to the loss of candor when discussing perceptions and opinions. The interview guides for each of the three groups will be carefully developed by Battelle to not only include a list of questions but also a useful rating scale to assess effectiveness of these approaches. Given the evolving and the continuous nature of these institutional changes, the rating scale has to be carefully calibrated to ensure consistency in responses. For example, changes in the number and nature of agreements will have to be carefully rated by agencies using a scale similar to this[11]:

Stage of Development	Establishing (1)	Functioning (2)	Maturing (3)	Sustaining (4)
Description	Initial formation with small leadership core working on mobilization and direction	Follows the completion of initial activities, focus on structure and more long range programming	Stabilized roles, structures, and functions; Confronted with conflicts to transform and "growing pains"	Established organization and operations, focus on higher level changes and institutionalizing efforts

In the pre-deployment interviews, interviewees will be asked to weigh the importance of various hypothesized institutional and organizational impacts (hypotheses). These weights will be considered when analyzing and reporting the evaluation findings.

5.8.3.2 Content Analysis

The content analysis will be carried out using the overall approach directed by two key questions: 1) what did the partners do to try to make their ICM projects successful?; and 2) what were the keys to success and what are the associated lessons learned that will be useful to U.S.DOT and other state and local transportation agencies? Three key areas are identified for content analysis:

- Outreach Materials/Activities: To the extent possible, all outreach materials related to the ICM project that are created and distributed by local partner agencies (or any marketing/communications contractors) will be compiled and archived by San Diego and Dallas and transmitted by project partners to the national evaluation team in electronic format during both baseline and post-deployment periods. In addition, any outreach activities conducted by the partner agencies and any marketing/communications contractors will be logged and reported by the project partners to the national evaluation team during these same periods.
- Partnership documents: To the extent possible, all ICM partnership documents will be archived and given by project partners to the national evaluation team in electronic format during the baseline stage. Partnership documents include the original proposal and teaming agreement obtained from U.S. DOT as well as communications among partners during the proposal development and project implementation stages (i.e., baseline).
- Media Coverage: From its first occurrence, all local, regional, and national media coverage of the ICM will be sought for the national evaluation. The primary source for the data will be the project partners and the Knowledge and Tech Transfer Team who will provide media clippings from local media sources pertaining to the ICM project.

[11] Final Evaluation Design Document, "Drug-Free Communities Support Program National Evaluation," Battelle, July 1, 2005

5.8.3.3 Case Studies or Table-Top Exercise

Case studies are an important part of the institutional analysis to assess suitability and effectiveness of ICM arrangements, especially if the case studies and the table-top exercises are repeated pre- and post-deployment. Stage II AMS results have clearly shown that the bulk of the benefits due to ICM are not evenly distributed over the demonstration phase but occur during discrete high-complexity situations. Capturing the changes in arrangements and capabilities during such situations is the primary objective of the case studies. Ideally, the evaluation would create a case study using a real-world example but it may be more convenient to develop a likely scenario and have the operators work through the event pre- and post- ICM.

5.8.3.4 Evaluation Results from Other Analyses

The Technical Capability Analysis (Section 5.1) looks at the improvements in the ability to monitor, control and report on the corridor which will serve as input to assess the realization of new capabilities in the corridor and assess if the investments/inputs occurred as planned.

5.8.4 Issues

No specific, significant challenges or issues have been identified. As with all of the analyses, the success of this analysis depends on the cooperation of the local partners in obtaining data. In this case, much of that data collection will involve interactions directly with the ICM stakeholders and, therefore, their cooperation in this analysis will manifest as commitment of their time. Areas for further specification in the site-specific test plans include identification of interviewees, development of specific questions for interviews, a schedule for data collection activities, and mechanisms for collecting the sites' documents and other materials referenced in Table 5-10 and preceding "Content Analysis" discussion.

6.0 NEXT STEPS

The national evaluation framework constitutes the first of the two-phased evaluation planning process for the national evaluation. Upon completion of this framework the evaluation team will immediately initiate development of the site-specific test plans—one test plan per evaluation analysis for each site. Those test plans will fully specify and finalize the required data elements and sources, specific mechanisms for collecting the data, timing of data collection and analysis activities, and detailed analytical approaches. Test plan development will include a visit to each site by several evaluation team analysis leaders. The timing of those site visits is to be determined but is expected to come near the beginning of test plan development, in approximately July 2011 for Dallas and August or September 2011 for San Diego.

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Appendix A – Master List of Candidate ICM Strategies from Foundational Research

The information in this appendix is from the report: "Integrated Corridor Management Phase 1 – Concept Development and Foundational Research, Task 5.2 – Operational Approaches, Draft Final Technical Memorandum," prepared for FHWA and FTA by the SAIC team, December 22, 2005.

Approach A: Information Sharing / Distribution

1. **Manual information sharing.** This type of information sharing involves first responders or TMC operators physically calling, radioing, faxing or emailing relevant stakeholders information about incidents or construction.
2. **Automated information sharing (real-time data).** This type of information sharing is done through systems (i.e., computers, database servers) communicating directly to one another to transmit data via center-to-center protocols.
3. **Automated information sharing (real-time video).** This type of information sharing is done through systems (i.e., video servers / switcher) communication directly to one another to transmit video images through video protocols.
4. **Information clearing-house / Information Exchange Network between corridor networks / agencies.** An information clearing-house or IEN consists of a software system that collects, aggregates, warehouses, and distributes traffic flow / transit performance data and incident / construction information. Corridor agencies can access this system to enter their own information and to view information for all the participating agencies and networks.
5. **A corridor-based advanced traveler information system (ATIS) database that provides information to travelers pre-trip.** An ATIS system can provide real-time information pre-trip to travelers via websites and 511. It may also be used as part of a multi-modal trip itinerary planning tool. Travelers can use this information in order to determine when to depart for their trip and what route and mode to use.
6. **En-route traveler information devices owned / operated by network agencies (e.g., DMS, 511, transit public announcement systems) being used to describe current operational conditions on another network(s) within the corridor.** En-route traveler information devices provide travelers with information on construction, incidents, congestion, delays and travel times. This information may be used by travelers to change their route, and possibly their mode, mid-trip based on the current conditions within the corridor and adjacent networks. (Note – DMS can include dynamic message signs on the freeway and arterial, as well as transit in-terminal and wayside DMS. Transit public announcement systems can include in-vehicle annunciation and in-terminal announcements. Kiosks in terminals, rest areas, etc., may also be considered "en –route traveler information devices.)
7. **A common incident reporting system and asset management (GIS) system.** Common incident reporting and asset management systems allow corridor agencies to share and view incident information for the entire corridor as well as use the infrastructure of all agencies to provide the best information to travelers and incident response.
8. **Shared control of "passive" ITS devices, such as CCTV (i.e., camera selection, pan / tilt / zoom).** This builds upon the automated sharing of video, allowing agencies to select specific cameras (owned by other agencies within the corridor) and view the resulting video. It also allows outside agencies to control the camera (e.g., a transit agency changing the orientation of a freeway camera to view conditions at a nearby station / bus stop. By allowing shared control and leveraging equipment, corridor agencies may also reduce duplicate equipment and save money.
9. **Access to corridor information (e.g., ATIS Database) by Information Service Providers (ISPs) and other value-added entities.** Access to the ATIS system by value-added entities can provide travelers with real-time traveler information pre-trip and en-route. This information can be used in conjunction with in-vehicle navigation systems to automatically route travelers around incidents, construction, and other congestion problems.

Approach B: Improve Operational Efficiency of Network Junctions & Interfaces

1. **Signal priority for transit (e.g., extended green times to buses that are operating behind schedule).** Extending green times to late buses helps to get the bus back on schedule and maintain their scheduled headways between other buses. By increasing the schedule reliability, bus companies might be able to reduce the number of buses required for operations.
2. **Signal pre-emption / "best route" for emergency vehicles.** Signal preemption turns the signal green for the emergency vehicles immediately after a minimum green time and clearance has been achieved on the perpendicular approach. This allows emergency vehicles to arrive at their destination more quickly. It also can enhance intersection safety by reducing the number of red lights the emergency vehicle may have to run.
3. **Multi-modal electronic payment.** Multi-modal electronic payment provides an efficient way for travelers to pay for highway tolls as well as transit / ferry fares and parking fees, all using a single fare payment system (including back office processing and billing/ payment) and electronic device. Multi-modal electronic payment increases the number of vehicles / passengers that can be processed per hour, and can facilitate transfers and shifts between services and networks.
4. **Transit hub connection protection (holding one service while waiting for another service to arrive).** The most common example of this strategy involves holding buses for trains – for example, if a commuter train full of passengers is going to arrive a few minutes late, the local bus(es), (on which several of these train passengers are expected to board), will be held at the rail terminal so that these passengers do not have to wait for the next bus (which may be several minutes later or longer). Connection protection better coordinates transfers at designated locations to create seamless transit service and reduces transfer times and trip times. Connection protection helps increase passenger satisfaction with transit service and encourages ridership.
5. **Multi-agency / multi-network incident response teams / service patrols and training exercises.** This strategy involves incident response or service patrols operated by one agency (e.g., freeway, tunnel agency) leaving that agency's network to assist with an incident or other problem on another agency's facility (e.g., nearby arterial), particularly when the other agency's team can arrive at the scene in a more timely manner. Coordinating incident response teams and service patrols not only saves money (by sharing resources), but also provides a more coordinated, efficient response to incidents in the corridors. Coordinating training exercises allows each agency to understand their role in incident management and prepare for it prior to an incident.
6. **Coordinated operation between ramp meters and arterial traffic signals in close proximity.** Coordination of ramp meters and traffic signals may involve changing the signal timing (e.g., left turn phase onto the freeway entrance ramp) in real time such that ramp queues do not back up into the mainline of the arterial. Similarly, depending on demand at the signalized intersection, the timing of the ramp meter may be adjusted.

Approach C: Accommodate / Promote Cross-Network Route & Modal Shifts

a – Passive Network Shifts ("Inform") – Accommodate any user-determined network shifts that occur in response to the Information Sharing Strategies.

1. **Modify arterial signal timing to accommodate traffic shifting from freeway.** As users start shifting from the freeway to an arterial (based on information received from traveler information devices), arterial signal timing plans (i.e., cycle length, phase splits, offsets) can be altered to better accommodate the additional traffic along the arterial. This can be accomplished on a real-time traffic adaptive basis; or special timing plans can be developed in advance, stored in the system, and activated manually or via a traffic responsive algorithm.
2. **Modify ramp metering rates to accommodate traffic, including buses, shifting from arterial.** As users start shifting from an arterial to the freeway, ramp metering rates can be modified (or metering activated, if not normally in operation during that time of day) in order to better manage the additional ramp traffic trying to access the freeway. This could mean increasing the metering rates (vehicles / hour on the regular lanes and/or HOV lanes) to reduce queues on the ramp and arterial), or decreasing the metering rates to prevent the freeway from breaking down.
3. **Modify transit priority parameters to accommodate more timely bus / light rail service on arterial.** As users start shifting to transit modes (i.e., bus or light rail), transit priority parameters (e.g., the amount of time a transit vehicle must be behind schedule before the signal is pre-empted) can be modified to ensure buses / light rail vehicles stay on schedule. This may be necessary due to increased (shifted) traffic along the arterial and / or increased passenger volumes (necessitating longer boarding times.

b – Promote Network Shifts ("Instruct")

4. **Promote route shifts between roadways via en-route traveler information devices (e.g., DMS, HAR, "511") advising motorists of congestion ahead, directing them to adjacent freeways / arterials.** This is a more proactive version of strategy A-6. In addition to just describing current operational conditions within the corridor, the en-route devices will also suggest or direct (depending on the seriousness of the situation) users to utilize an alternative roadway network. By instructing users which alternate routes to use, agencies can balance the traffic between various alternate routes in order to reduce congestion and delay on any one particular route (assuming that the alternative route(s) have spare capacity).
5. **Promote modal shifts from roadways to transit via en-route traveler information devices (e.g., DMS, HAR, "511") advising motorists of congestion ahead, direction them to high-capacity transit networks and providing real-time information on the number of parking spaces available in the park and ride facility.** This is a more proactive version of strategy A-6. In addition to just describing current operational conditions within the corridor, the en-route devices will also suggest or direct (depending on the seriousness of the situation) users to utilize an alternative transit network (e.g., rail transit, light rail, bus rapid transit), and where to transfer from their car to transit. By instructing users on parking availability and transit routes, agencies can balance the usage between roadways and transit, as well as balance the usage between different park and ride facilities (assuming that the alternative route(s) have spare capacity).
6. **Promote shifts between transit facilities via en-route traveler information devices (e.g., station message signs and public announcements) advising riders of outages and directing them to adjacent rail or bus services.** This is a more proactive version of strategy A-6. In addition to just describing current operational conditions on the transit networks within the corridor, the en-route devices will also suggest or direct (depending on the seriousness of the situation) users to utilize an alternative transit network. Directing users to adjacent rail or bus services allows agencies to reduce confusion and more efficiently move users around transit outages.
7. **Re-route buses around major incidents.** This strategy is similar to "promoting route shifts between roadways", but focuses on buses. It involves altering normal bus routes in order to avoid major congestion along these routes, thereby helping the buses to maintain their schedules. Because rerouted buses may miss some of their normal stops, information should be provided to transit users at those stops so they know not to wait for the bus and to use another stop.

Approach D: Manage Capacity – Demand Relationship Within Corridor – "Real-time" / Short-Term

Promoting cross-network shifts assumes **available capacity** on the adjacent networks and network linkages and junctions (e.g., park and ride facilities). If not, it may be necessary to either increase the capacity of these alternate networks, to implement strategies to reduce demand, or some combination. The capacity and demand strategies identified below can be implemented in real-time, or within a matter of hours, and with results shortly thereafter.

a – Capacity Oriented

1. **Lane use control (reversible lanes / contra-flow).** Lane use control – providing contra-flow or reverse laning as it is also commonly known – can be used to provide additional capacity on roadways. It involves the reversal of traffic flow in one or more of the lanes (or shoulders) in one direction for use in the other direction. The goal is to increase capacity in a particular direction, thereby reducing congestion in that direction by opening extra lanes for all traffic (or just for HOV traffic). This strategy can be implemented for evacuations, emergencies or special events. Moreover, with the installation of overhead lane – use signals and / or delineation devices (e.g., moveable barriers), this strategy can be also used to manage capacity on a regular basis (e.g., daily peaks).
2. **Convert regular lanes to "transit-only" or "emergency-only".** Regular lanes can be converted to "transit-only" lanes to improve bus operations along the roadway during an incident, emergency, special event, or unusual demand, thereby improving bus service and encouraging transit ridership. Regular lanes can also be converted to "emergency-only" to allow quickly and timely movement of emergency vehicles during an incident or emergency.
3. **Add transit capacity by adjusting headways and number of vehicles.** Increasing the number of transit vehicles (e.g., bus, rail), and reducing the headways between these transit vehicles, increases the transit capacity, thereby providing a more convenient and attractive service for users who may need to shift modes within the corridor. This strategy assumes that the transit agencies have the additional vehicles and the available personnel to operate these vehicles.
4. **Add transit capacity by adding temporary new service (e.g., express bus service, "bus bridge" around rail outage / incident).** A bus bridge / express bus service is temporary bus service between rail stations for moving rail passengers around a rail outage or incident. Express bus services can fill the gaps where there are no rail services, and / or where the rail service is operating at capacity and there is high demand and some roadway opportunities to allow longer distance travelers to bypass closer in stops. Express buses often involve a collector portion where several stops or even local service is offered and then operate a non-stop segment on a freeway. Occasionally, "express" service operates on arterials and may include some limited stops.
5. **Add capacity at parking lots (temporary lots).** This strategy involves providing capacity at temporary parking lots and /or near-by garages, and perhaps also providing bus service between the transit station and the temporary parking. This allows drivers to shift modes from roadway to transit, particularly during an incident on the roadway network.
6. **Increase roadway capacity by opening HOV / HOT lanes / shoulders.** Opening shoulders and / or HOV / HOT lanes to all roadway traffic will increase the roadway vehicular capacity, and may be appropriate during incidents, construction, unusual peak demand, special events. Depending on the typical HOV / HOT use, it may actually decrease the "person-carrying" capacity of the roadway. Opening shoulders to traffic may have safety ramifications.
7. **Modify HOV restrictions (increase minimum number, make bus only).** HOV restrictions can be modified to increase the minimum number of vehicle occupants (e.g., from HOV- 3 to HOV-4), or converted to "bus / van pool only", thereby increasing the person-carrying capacity of the roadway network. Such a strategy would likely be used in conjunction with other strategies to increase bus service.

Approach D: Manage Capacity – Demand Relationship Within Corridor – "Real-time" / Short-Term

8. **Restrict ramp access (metering rates, closures).** When the freeway flow has broken down, or in the event of a major incident or contra-flow operations, freeway on-ramps within the vicinity may be closed, or more restrictive metering rates may be implemented, to prevent or limit further traffic from entering the freeway. Similarly, in the event of a problem on an adjacent arterial, freeway off-ramps may be closed.
9. **Restrict / Reroute Commercial Traffic.** During special events or major incidents, it may be necessary to restrict commercial traffic access to and within the corridor, provided an alternative route around the corridor can be provided.
10. **Re-routing rail transit to alternative rail networks.** Allowing light rail to operate on an adjacent rail network would permit rail to re-route around an outage, with minimal disruption to service and eliminating the need for a bus bridge. The operation of transit and freight trains on the same tracks would also allow regions to increase transit and freight rail capacity in corridors without requiring significant infrastructure improvements (e.g., purchasing new rail rights-of-way). There are several issues associated with this strategy, including liability, incompatibility of equipment, non-uniform operating rules and procedures and federal safety restrictions/regulations of the Federal Railroad Administration (FRA). This strategy is identified as "short term" from an operational perspective. However, in general, such a strategy is currently not possible. The FRA does not allow "non-compliant" vehicles (e.g., light rail vehicles) to operate on the same tracks (concurrent operations) with "compliant vehicles" (e.g., freight rail cars, commuter rail cars). Commuter rail cars are allowed to operate on the same tracks with freight rail cars at the same time as long as they are FRA "compliant" (e.g., having sufficient buff strength). Rail shared use operation of compliant and non-compliant rail vehicles is only permissible with an FRA waiver, which allows the practice to take place using "temporal" separation (e.g., light rail runs during the day, freight rail runs during the night). Integrated, or concurrent, rail shared use operations is currently not permissible in the U.S. In addition, the correct infrastructure (e.g., cross-overs) must be in place in order to implement this strategy. Thus, while this strategy may be considered "short term" from an operational perspective, making this strategy feasible for implementation will involve a relatively long term process.

b – Demand Oriented

11. **Variable speed limits (based on TOD, construction, weather conditions).** Variable speed limits can be used to manage traffic in the vicinity of incidents and construction activities, in adverse weather conditions and during heavy peak period travel times. Reducing speed limits helps to reduce the possibility of flow breakdown (e.g., due to increased traffic from other networks), as well as to reduce secondary incidents during these time periods.
12. **Modify toll / HOT pricing.** Toll / HOT pricing can either be increased or decreased in order to influence traffic demand on a particular toll facility. For example, if there was a major incident on a free river crossing, the tolls on an adjacent toll bridge / tunnel could be suspended. Similarly, in the event of a significant increase in demand, tolls could be increased as a way to shift travelers to transit.
13. **Modify transit fares to encourage ridership.** This strategy parallels D-11 in many respects -- transit fares can be reduced (e.g., during special events and major incidents) in order to encourage users to ride transit instead of utilizing the highway.
14. **Modify parking fees.** Parking fees can be decreased at park and ride lots – including temporary lots – to encourage corridor users to utilize transit. Similarly, parking fees at the major destinations within the corridor (e.g., CBD) could also be increased to influence roadway demand.
15. **Variable truck restrictions (lane, speed, route, time of day).** Trucks can be prohibited during AM and PM peak hours in order to provide more capacity for commuters.
16. **Re-route thru-traffic (e.g., trucks) away from corridor (likely a regional issue).** Through traffic with no origin or destination within the corridor can be routed around the corridor in order to provide more capacity for origin / destination users.

Approach E: Manage Capacity – Demand Relationship Within Corridor – Long-Term

These capacity and demand strategies are long-term in nature – with respect to the amount of time required to develop and deploy the strategies, the time require for the desired results to accrue, or some combination. They are not ICM operational strategies, per se; but they can certainly benefit and enhance integrated corridor management and the associated strategies.

a – Capacity Oriented

1. **Low cost infrastructure improvements to cross-network linkages and junctions.** Improvements such as auxiliary / turning lanes, additional parking at transit stations and terminals, ramp widening, new ramps (e.g., direct access between freeway and park-and-ride lots), improved signal displays / coordination, guide signing, illumination, etc. can greatly improve the operation of the corridor in terms of increased capacity and better traveler information and guidance. In some cases – particularly where limited spare capacity exists within the corridor – these actions may be necessary to support route and mode shifts as part of the ICM. An associated strategy is for transit agencies to purchase (or lease) additional rolling stock that can be used in the event additional transit capacity is required.

b – Demand Oriented

2. **Guidelines for work hours during emergencies / special events.** Corridor agencies can work with employers to establish alternate work hours (e.g., staggered release times) in order to reduce congestion during special events or during an emergency requiring an orderly evacuation.
3. **Peak spreading.** Peak spreading involves promoting flexible work hours or telecommuting to reduce congestion. Doing this helps to stretch the peak hours over a greater amount of time thus reducing congestion within the corridor.
4. **Ride-sharing programs.** Corridor agencies can establish ride share programs to match users traveling to and from similar origins and destinations in order to increase the efficiency of the corridor by reducing single occupancy cars.

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