Integrated Corridor Management Initiative: Demonstration Phase Evaluation

Dallas Corridor Performance Analysis Test Plan

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LIST OF ABBREVIATIONS

1/3	One-third
AMS	Analysis, Modeling and Simulation
APC	Automatic Passenger Counter
AVL	Automatic Vehicle Location
AVO	Average Vehicle Occupancy
BI	Buffer Index
CRIS	Crash Records Information System
DART	Dallas Area Rapid Transit
DMS	Dynamic Message Sign
DSS	Decision Support Systems
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GP	General Purpose
GUI	Graphical User Interface
НОТ	High-Occupancy Tolling
HOV	High-Occupancy Vehicle
I-15	Interstate-15
I-635	Lyndon B. Johnson Freeway
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
ITS	Intelligent Transportation Systems
KTT	Knowledge and Technology Transfer
LBJ	Lyndon B. Johnson Freeway
LRT	Light Rail Transit
MOE	Measure of Effectiveness
NCTCOG	North Central Texas Council of Governments
NTTA	North Texas Tollway Authority
O-D	Origin-Destination
PHT	Person-Hours Traveled
PMT	Person-Miles Traveled

PT	Person Throughput
PTI	Planning Time Index
PTT	Person Travel Time
RITA	Research and Innovative Technology Administration
SOV	Single-Occupant Vehicle
TEARS	Targeted Event Accelerated Response System
TT	Travel Time
TTI	Travel Time Index
TxDOT	Texas Department of Transportation
UMD	University of Maryland
U.S. DOT	U.S. Department of Transportation
VHT	Vehicle-Hours Traveled
Vi	Count of Vehicles
VMT	Vehicle-Miles Traveled
Volpe Center	John A. Volpe National Transportation System Center
VPHPL	Vehicles Per Hour Per Lane
VT	Vehicle Throughput
VTT	Vehicle Travel Time

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1.0 INTRODUCTION

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

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

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

1.1 ICM Program¹

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

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

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

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

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

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

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

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

An on-going ICM Initiative activity, AMS is very relevant to the evaluation. AMS tools were developed in Phase 2 and used by the sites to identify and evaluate candidate ICM strategies. In Phase 3, the proposed Dallas and San Diego ICM deployments were modeled. As sites further

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refine their ICM strategies, AMS tools continue to be used and iteratively calibrated and validated, using key evaluation results, in part. The AMS tools are very important to the evaluation for two reasons. First, the evaluation will produce results that will be used to complete validation of the AMS tools, e.g., assumptions related to the percentage of travelers who change routes or modes in response to ICM traveler information. Second, AMS tools will serve as a source of some evaluation data, namely the corridor-level, person-trip travel time and throughput measures that are difficult to develop using field data.

1.2 ICM Demonstration Phase Deployments²

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

1.2.1 Overview of the Dallas ICM Deployment

The U.S. 75 ICM project is a collaborative effort led by Dallas Area Rapid Transit (DART) in collaboration with U.S. DOT; 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 (travelshed) has 167 centerline-miles (269 kilometers) of arterial roadways.

Exhibited in Figure 1-1, the U.S. 75 corridor has two concurrent flow-managed, high-occupancy vehicle (HOV) lanes, light rail, bus service, and park & 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 ICM deployment. The Dallas ICM deployment focuses on the four primary ICM goals shown in Table 1-1: improve incident management, enable intermodal travel decisions, increase corridor throughput, and improve travel time reliability. The Dallas site team intends to utilize a variety of coordinated, multimodal operational strategies to achieve these goals, including:

• Provide comparative travel times between various points of interest to the public via the 511 system for the freeway, strategic arterial streets (i.e., Greenville Ave.), 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.

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

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- Use simulations to predict travel conditions for improved operational response.
- Implement interdependent response plans among agencies.
- Divert traffic to strategic arterials and frontage roads with improved, event-specific traffic signal timing response plans.
- Shift travelers to the light-rail system during major incidents on the freeway.



Figure 1-1. U.S. 75 Corridor Boundaries of Dallas ICM Deployment

Table 1-1. Dallas ICM Project Goals

	Improve Incident Management
Goal #1	• 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
Goal #2	• Provide travelers a holistic view of the corridor and its operation through the delivery of timely, accurate and reliable multimodal information, to allow 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
Goal #3	• Agencies within the corridor have worked to increase throughput on their individual networks from supply and operations points of view, and will continue to do so. The ICM 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
Goal #4	• 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.

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

- A Decision Support System (DSS) that will utilize incoming monitoring data to assess conditions, forecast conditions up to 30 minutes in the future, and then formulate recommended response plans (including selecting from pre-approved plans) for consideration by operations personnel. Table 1-2 summarizes expected Dallas DSS functionality.
- Enhancement of the SmartNET regional information exchange network, a system that was recently implemented using non-ICM funding and which is being enhanced using ICM funding, including expanding the number of agencies able to exchange data through the system. SmartNET is a commercial data integration and dissemination tool with a common graphical user interface (GUI). SmartNET provides a conduit for input, fusion and shared, multi-agency access to a variety of transportation condition data.
- A 511 telephone and web-based traveler information system for the region.
- Development of new, event-specific traffic signal timing plans to support traffic diversions onto Greenville Avenue (termed the "Targeted Event Accelerated Response System," or TEARS).
- Arterial street monitoring system, including additional travel time detectors (Bluetooth).
- Using non-ICM funds, various supporting transit improvements including mobile data terminals and automatic vehicle location system replacement.
- Parking management systems for key park & ride lots.

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Functionality	Summary
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. The decision to separate response plan selection functionality from prediction functionality was also based on prediction accuracy considerations. Another important part of the DSS Expert System module is the periodic (most likely monthly or if feasible every 2 weeks) post-review of action plans implemented and modifying them as needed.
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. This will be augmented with the deployment of Bluetooth readers for a real-time arterial monitoring system. 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 at regular time intervals or "on the fly" 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 recommend a candidate response plan 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 recommendation 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.

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It is expected that the various Dallas 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 system 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. These lasting changes may be 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 to other, non-ICM related changes such as regional travel demand.

1.2.2 Dallas ICM Deployment Schedule

Table 1-3 presents the latest, formal, U.S. DOT-approved Dallas ICM deployment schedule. As is often the case with large, complex technology deployments, it is quite possible that this schedule may slip over time. The schedule of data collection and analysis activities presented throughout this test plan reflect the latest schedule but they will be adjusted as necessary in response to any future changes in the deployment schedule.

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

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Activity	Completion Date
Complete Planning Phase	December 2010
Complete Design Phase	February 2012
Build Phase (complete unit testing):	
Arterial Street Monitoring System	April 2012
Mobile Web	
511 Interactive Voice Response (phone)	April 2012
My 511 (Web)	April 2013
Social Networking	
Transit Signal Priority	August 2012
Event Specific Traffic Signal Timing Plans (Targeted Event Accelerated Response System)	September 2012
DART Data Portal	
Video Sharing	October 2012
SmartNET/Smart Fusion (including all integration of new ICM data) IT Infrastructure	00000012012
Decision Support System	November 2012
Complete Integration Testing	January 2013
Complete Acceptance Testing/Operations Go Live	April 8, 2013
Complete Shakedown Period	October 8, 2013
Complete Evaluation One Year Operational Period	October 7, 2014

Table 1-3.	Dallas ICM	Deployment	Schedule

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1.2.3 Comparison to the San Diego ICM Deployment

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

- The Dallas U.S. 75 corridor includes the Red Line light rail transit (LRT) service whereas the I-15 corridor in San Diego will include extensive bus rapid transit (being implemented separately from and immediately prior to ICM).
- The Dallas U.S. 75 corridor includes concurrent flow HOV lanes whereas the San Diego corridor includes concurrent flow high-occupancy tolling (HOT)/managed lanes:
 - The San Diego corridor includes a recently expanded four-lane managed lane system in the I-15 median that is variably priced high occupancy tolling and includes two reversible center lanes. The San Diego site team does not expect

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ICM to impact their variable pricing decisions but it will impact their use of the four configurable managed lanes.

- The Dallas U.S.-75 corridor includes access-controlled, HOV lanes located in the median, although, like San Diego with the HOT lanes, they do not expect ICM to impact their occupancy requirement decisions.
- Both sites currently lift HOV restrictions during major incidents.
- Both sites include major arterials that run parallel with the freeways. However, while the arterial in Dallas is continuous for the length of the corridor, there is no single continuous arterial running parallel to I-15 in San Diego; Black Mountain Road, Pomerado Road, and Centre City Parkway are parallel arterials in the I-15 corridor.
- The Dallas corridor includes an extensive frontage road system, while the San Diego I-15 corridor includes auxiliary lanes between most freeway interchanges that function similarly, though with less capacity.
- The San Diego corridor includes ramp meters on I-15 and so their traffic signal timing strategies include ramp meter signals. Dallas does not use ramp meters.
- Both sites include responsive traffic signal control. Dallas is not upgrading any traffic signal controllers, but has responsive 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.

1.3 National Evaluation Objectives and Process

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

1.3.1 U.S. DOT Hypotheses

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

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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 n modal corridor performance, particularly in high travel demand and/or red capacity periods.			
Have Benefits Greater than Costs	Because ICM must compete with other potential transportation projects for scarce resources, ICM should deliver benefits that exceed the costs of implementation and operation.		
The implementation of ICM will have a positive or no effect on:			
Air Quality Air Quality 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, an better incident management may reduce the occurrence of secondary cr			
Decision Support Systems* Decision support systems provide a useful and effective tool for ICM provide managers through its ability to improve situational awareness, enhance response and control mechanisms and provide better information to tra- resulting in at least part of the overall improvement in corridor performance			

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

1.3.2 Evaluation Analyses

The investigation of the eight U.S. DOT evaluation hypotheses have been organized into seven evaluation "analyses." Table 1-5 associates six of those seven analyses with specific U.S. DOT hypotheses; the seventh analysis not shown in Table 1-5 investigates institutional and organizational issues and relates to all of the hypotheses since the ability to achieve any intended ICM benefits depends upon successful institutional coordination and cooperation.

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	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

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

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

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

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

1.3.3 Evaluation Process and Timeline

Figure 1-2 shows the anticipated sequence of evaluation activities. The evaluation will collect 12 months of baseline (pre-ICM deployment) data and, following a 6-month shakedown period, 12 months of post-deployment data.

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



Figure 1-2. Sequence of Evaluation Activities

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

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

1.3.4 Roles and Responsibilities

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

2.0 MOBILITY ANALYSIS

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

2.1 Analysis Overview

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

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

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

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Figure 2-1. Overview of Mobility Analysis

2.1.1 Hypothesis Testing

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

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

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

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Overall ICM Mobility Hypotheses:

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

ICM Strategy-Specific Hypotheses:

- Dissemination of en-route traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput.
- Dissemination of en-route traveler information will encourage route shifts and result in increased corridor vehicle and person throughput.
- Provision of pre-trip traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput.
- Provision of pre-trip traveler information will encourage route shifts and result in increased corridor vehicle and person throughput.
- Coordination of traffic signals will reduce overall delay, improve travel time and travel time reliability and increase throughput.
- Implementation of incident timing plans during incidents will reduce overall delay and improve travel time, throughput, and travel time reliability.
- Temporary LRT capacity added in real-time during major incidents and/or unusually high demand periods will be utilized by travelers and thus contribute to improved person throughput.

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

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Data	Element	MOE	Hypotheses
Quantitative Data			
1. Traffic Volume	1.1 U.S. 75 General Purpose Lane Traffic Volume	 Changes in vehicle throughput – corridor-wide and O-D pairs, by mode and direction Changes in vehicle throughput – freeway general purpose (GP) lanes Changes in vehicle-miles traveled – corridor-wide and O-D pairs, by mode and direction Changes in vehicle hours traveled – corridor-wide and O-D pairs, by mode and direction Support the analysis of person throughput measures (person-miles traveled and person-hours traveled) Support the analysis of incident recovery time 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput Dissemination of en-route traveler information will encourage route shifts and result in increased corridor vehicle and person throughput Provision of pre-trip traveler information will encourage route shifts and result in increased corridor vehicle and person throughput
	1.2 U.S. 75 HOV Lane Traffic Volume	 Changes in vehicle throughput – corridor-wide and O-D pairs, by mode and direction Changes in vehicle throughput – freeway HOV lanes Changes in vehicle-miles traveled – corridor-wide and O-D pairs, by mode and direction Changes in vehicle hours traveled – corridor-wide and O-D pairs, by mode and direction Changes in vehicle hours traveled – corridor-wide and O-D pairs, by mode and direction Support the analysis of person throughput measures (person-miles traveled and person-hours traveled) Support the analysis of incident recovery time 	
	1.3 Arterial and Frontage Road Intersection Traffic Volume	 Changes in vehicle throughput – corridor-wide and O-D pairs, by mode and direction Changes in vehicle throughput – arterials/frontage roads Changes in vehicle-miles traveled – corridor-wide and O-D pairs, by mode and direction Changes in vehicle hours traveled – corridor-wide and O-D pairs, by mode and direction Changes in vehicle hours traveled – corridor-wide and O-D pairs, by mode and direction Support the analysis of person throughput measures (person-miles traveled and person-hours traveled) Support the analysis of incident recovery time 	

Data Element	MOE	Hypotheses	
Quantitative Data (Cont.)			
1. Traffic 1.4 Ramp Volume Volume (Cont.)	 Changes in vehicle throughput – corridor-wide and O-D pairs, by mode and direction Changes in vehicle throughput – freeway GP lanes Changes in vehicle throughput – arterials/frontage roads Support the analysis of person throughput measures (person-miles traveled and person-hours traveled) Support the analysis of incident recovery time 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput Dissemination of en-route traveler information will encourage route shifts and result in increased person throughput Coordination of traffic signals will reduce overall delay, improve travel time and travel time reliability and increase throughput Implementation of incident timing plans during incidents will reduce overall delay and improve travel time, throughput, and travel time reliability 	
2. Traffic 2.1 U.S. 75 Speed and General Travel Purpose Lane Time Traffic Speed	 Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction Changes in freeway GP lanes travel time Changes in total vehicle delay – corridor-wide and O-D pairs, by mode and direction Changes in total vehicle delay – freeway GP lanes Changes in average delay per vehicle Changes in travel time index – corridor-wide and O-D pairs, by mode and direction Changes in 80th, 90th and 95th percentile travel times – corridor-wide and O-D pairs, by mode and direction Changes in standard deviation of travel time – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in buffer index – corridor-wide and O-D pairs, by mode and direction 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes 	

Data	Element	МОЕ	Hypotheses	
Quantitative Da	Quantitative Data (Cont.)			
2. Traffic Speed and Travel Time (Cont.)	2.2 U.S. 75 HOV Lane Traffic Speed	 Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction Changes in freeway HOV lanes travel time Changes in total vehicle delay – corridor-wide and O-D pairs, by mode and direction Changes in total vehicle delay – freeway HOV lanes Changes in average delay per vehicle Changes in travel time index – corridor-wide and O-D pairs, by mode and direction Changes in 80th, 90th and 95th percentile travel times – corridor-wide and O-D pairs, by mode and direction Changes in standard deviation of travel time – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in buffer index – corridor-wide and O-D pairs, by mode and direction Support the analysis of incident recovery time 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes 	

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

Data Element	МОЕ	Hypotheses		
Quantitative Data (Cont.)				
2. Traffic Speed and Travel Time (Cont.) 2.3 Arterial and Frontage Road Travel Time	 Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction Changes in arterial/frontage road travel time Changes in total vehicle delay – corridor-wide and O-D pairs, by mode and direction Changes in total vehicle delay – arterials and frontage roads Changes in average delay per vehicle Changes in travel time index – corridor-wide and O-D pairs, by mode and direction Changes in 80th, 90th and 95th percentile travel times – corridor-wide and O-D pairs, by mode and direction Changes in standard deviation of travel time – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Changes in planning time index – corridor-wide and O-D pairs, by mode and direction Support the analysis of incident recovery time 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes 		

Data Element	МОЕ	Hypotheses	
Quantitative Data (Cont.)			
3. Roadway Geometry 3.1 U.S. 75 Geometry (number o lanes by segment, distance between ramps, and detector locations) 3.2 Arterials/	 Changes in vehicle and person throughput – corridor-wide and O-D pairs, by mode and direction Changes in vehicle and person throughput – freeway GP lanes Changes in vehicle and person throughput – corridor-wide and O-D 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes Coordination of traffic signals will reduce overall delay, improve travel time and travel time reliability and increase throughput Implementation of incident timing plans during incidents will reduce overall delay and improve travel time and throughput 	
Frontage Roads Geometry (number o lanes by lin and link lengths)	 Changes in vehicle and person throughput – control-wide and O-D pairs, by mode and direction Changes in vehicle and person throughput – arterials/frontage roads 		
4. Vehicle Occupancy Rate Occupancy Occupancy	 No direct linkage to a specific MOE; rather, support the analysis of person throughput MOEs 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes 	

Data	Element	МОЕ	Hypotheses
Quantitative Data (Cont.)			
4. Vehicle Occupancy Rate (Cont.)	4.2 Vehicle Occupancy in HOV Lanes	 No direct linkage to a specific MOE; rather, support the analysis of person throughput MOEs 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes
5. HOV Violation Rate	5.1 HOV Violation Rate	 No direct linkage to a specific MOE; rather, support the analysis of HOV lanes and corridor-wide vehicle and person throughput MOEs 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes

Data Element	МОЕ	Hypotheses		
Quantitative Data (Cont.)				
6. Transit 6.1 Transit Data Passenger Count	 Changes in transit passenger delay Changes in transit ridership Changes in transit person throughput Changes in incident/event-related throughput 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput 		
6.2 Transit automatic vehicle location (AVL) Data	 Changes in transit travel time Changes in transit vehicle delay Changes in transit passenger delay Changes in transit on-time performance 	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes Dissemination of en-route traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput Provision of pre-trip traveler information will encourage 		
6.3 Transit Schedule an Adherence	 Changes in transit vehicle delay Changes in transit passenger delay Changes in transit on-time performance 	 modal shifts and contribute to increased transit ridership and improved corridor person throughput Temporary LRT capacity added in real-time during major incidents and/or unusually high demand periods will be utilized by travelers and thus contribute to improved perso throughput. 		
7. Parking Capacity and Utilization7.1 Parking Lot Locations an Capacities7.2 Parking Lot Utilization	 Changes in transit ridership Changes in transit person throughput Changes in incident/event-related throughput 	 Dissemination of en-route traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput Provision of pre-trip traveler information will encourage modal shifts contribute to increased transit ridership and improved corridor person throughput Temporary LRT capacity added in real-time during major incidents and/or unusually high demand periods will be utilized by travelers and thus contribute to improved person 		
Data Element			МОЕ	Hypotheses
--------------------------------------------------------------------------	-------------------	-----------------------------------------------------------------------------------------	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
Quantitative Da	ita (Co	ont.)		
8. Maintenance and Construction Activities	8.1	Log of Maintenance Activities Log of Construction Activities	 No direct linkage to a specific MOE; rather, support the analysis of the following MOEs: Changes in vehicle throughput (including vehicle-miles and vehicle-hours traveled) – corridor-wide and O-D pairs, by mode and direction Changes in person throughput (including person-miles and person-hours traveled) – corridor-wide and O-D pairs, by mode and direction Changes in trip-weighted average vehicle travel time – corridor-wide and O-D pairs, by mode and direction Changes in total vehicle delay – corridor-wide and O-D pairs, by mode and direction Changes in average delay per vehicle Changes in travel time reliability (travel time index, 80th, 90th and 95th percentile travel times, standard deviation, planning time index and buffer index) – corridor-wide and O-D pairs, by mode and direction 	 Dissemination of en-route traveler information will encourage modal shift and contribute to increased transit ridership and improved corridor person throughput Provision of pre-trip traveler information will encourage modal shifts contribute to increased transit ridership and improved corridor person throughput
9. Events – Incidents, weather Events, and Special Events	9.1 9.2 9.3	Incident Records Weather Information Records Log of Special Events	 Changes in incident/event-related travel time, delay, throughput and travel time reliability Support the analysis of incident recovery time 	 Dissemination of en-route traveler information will encourage route shifts and result in increased person throughput Provision of pre-trip traveler information will encourage route shifts result in increased person throughput Implementation of incident timing plans during incidents will reduce overall delay and improve travel time and throughput Temporary LRT capacity added in real-time during major incidents and/or unusually high demand periods will be utilized by travelers and thus contribute to improved person throughput.

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

Data Element		МОЕ	Hypotheses
Quantitative Data (Cont.)			
10. AMS Data 10.1 Vehicle Throug for Arte and Fr Roads Corride 10.2 Person Throug for Arte and Fr Roads Corride 10.3 Vehicle Throug for Arte and Fr Roads Corride 10.3 Vehicle Throug for Arte and Fr Roads Corride 10.4 Person Throug for Arte and Fr Roads Trips 10.4 Person Throug for Arte and Fr Roads Trips	de• Chughput• Chrontage• Chrontage• Chdor• Chbon• Chughput• Chterials• Chcrontage• Chghput• Chdor• Chle• Chughput• Chterialscrontages - O Donughputterialscrontages - O Donughputterialscrontages - O D	anges in trip-weighted average vehicle travel time – corridor-wide d O-D pairs, by mode and direction anges in vehicle and person throughput – corridor-wide, by network d by mode anges in vehicle- and person-miles traveled – corridor-wide and O- pairs, by mode and direction anges in vehicle- and person-hours traveled – corridor-wide and O- pairs, by mode and direction	 The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes
11. Traffic11.1 TrafficData fromVolumI-35EI-35E	c • No ne on exc	direct linkage to a specific MOE; rather, allows for control of ogenous factors	 For control and evaluation of exogenous factors
Corridor 11.2 Traffic / Trave on I-35	c Speed • No vel Time exc 35E	direct linkage to a specific MOE; rather, allows for control of ogenous factors	For control and evaluation of exogenous factors

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

Data	Element	MOE	Hypotheses				
Quantitative Da	Quantitative Data (Cont.)						
12. Ridership Data on Other LRT Lines	12.1 Ridership Data on other LRT Lines	 No direct linkage to a specific MOE; rather, allows for control of exogenous factors 	 For control and evaluation of exogenous factors 				
13. Event Case Studies	13.1 Notification of Occurrence of Candidate Event Case Studies	 No direct linkage to a specific MOE; rather, allows the analysis of many MOEs 	 No direct linkage to a specific hypothesis; supports analysis related to many hypotheses 				
Qualitative Data							
This analysis uti	This analysis utilizes no qualitative data						

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2.1.2 Mobility Evaluation MOEs and the Logic Model

As noted in section 1.3.2, the ICM evaluation utilizes the "Logic Model" construct for categorizing various evaluation measures of effectiveness and understanding the causal (and typically sequential) relationships among those measures. The logic model categorizes impact MOEs as either "outputs" or "outcomes." Outputs are what the ICM investments ("inputs") generate directly—such as traffic data generated by a new sensor—or which are generated by the system operators using the ICM investments, such as more coordinated responses to incidents or congestion. Outcomes describe the impact of the ICM investments (and the outputs generated by and through those investments) on travelers, the transportation system, and the environment. In the same way that outcomes are dependent upon preceding investments and outputs, there are causal relationships or dependencies among outcomes. For example, as symbolized by the "tiers" in Figure 2-2, although some transportation system impacts such as mobility or safety may be influenced directly by outputs (e.g., changes in traffic signal timing plans) many of them many are at least partially dependent on traveler responses to the ICM system and system operators' actions (inputs and outputs). Finally, as shown in Figure 2-2, there are causal, sequential relationships within the outcome category of "traveler response." That is, changes in traveler behavior based on enhanced ICM traveler information are dependent on the travelers first being aware of the traveler information. In the larger sense, these are still "outcomes" travelers' awareness and consultation of ICM-enhanced traveler information is certainly an outcome of the ICM system operators' generation and dissemination of that information (outputs)—but within the traveler response tier awareness and use can be seen as a necessary precedents to changes in traveler behavior based on the enhanced traveler information.



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

2.1.3 Special Considerations

2.1.3.1 Phased Implementation of ICM Projects

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

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

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

For some MOEs, such as arterial street travel times, it is expected that no comprehensive historic data will be available. If, as is currently expected, ICM projects and associated strategies are implemented early in the baseline year that will impact such that MOE, the evaluation will by necessity focus strictly on a comparison of the baseline year conditions ("tainted" though they may be in regard to certain projects and associated impacts) with post-full ICM deployment

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conditions. This is consistent with the notion that the "after" or "with ICM" condition is truly defined by implementation and operation of the <u>entire</u>, <u>fully-integrated ICM system</u> rather than by when the first, separate ICM-enabling or –related project is implemented. Thus, when necessary, the baseline year—impacted as some evaluation MOEs may be by "early-deployed" ICM projects and strategies—can still serve meaningfully as the "pre-ICM" condition.

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

2.1.3.2 Prompt Identification of Specific Event Case Studies

As elaborated in Sections 2.2.13 and 2.4.3, the mobility analysis features examination of a limited number of specific "event case studies:" major incidents, minor incidents, severe weather events, and planned special events. Some of these same, specific events will be analyzed in other evaluation analyses and some of those analyses will entail ad hoc data collection that will need to be initiated within a couple of days of the occurrence of the event, notably the "pulse" traveler surveys planned by the Volpe Center. Therefore, it will be important for the Dallas site team to notify the national evaluation team within 72 hours when any events occur that represent candidate national evaluation event case studies. In order for the Dallas site team to do that, they need a "watch list" of events—a list of defining characteristics or profiles for the type of events of interest to the national evaluation team. As elaborated in Section 2.4.3, this draft test plan does not contain that watch list as its preparation relies upon historic incident data that has not yet been acquired from the Dallas site team. This watch list will be prepared prior to the beginning of the baseline data collection year.

2.2 Quantitative Data

This section identifies the quantitative data elements to be used in the mobility portion of the corridor performance analysis. Table 2-2 summarizes the data requirements for the mobility analysis. The details associated with the source, timing, and other aspects of each data element are discussed in the sections that follow.

The "start" dates for data collection in Table 2-2 generally note the start of the one-year baseline data collection period. As discussed in Section 2.1.3.1, available historic data will also be collected. That data will provide a sense of the overall, longer-term trends in key MOEs such as traffic volumes and transit ridership and, if necessary, provide a clean "pre-ICM" condition for certain MOE analyses in those cases where ICM projects and associated strategies are implemented very early in the baseline period—the 12 months preceding the overall ICM system go-live.

	Data Element	Location		Data Collection	Data Collection Period ³		Data Collection	Data Transmittal	
		Start	End	Frequency	Start	End	Responsible Party		
1.1	U.S. 75 GP Lane Volume	Highway 121	South Terminus in Dallas	5-min	April 2012	October 2014	ICMS Data Feed	Continuous (University of Maryland [UMD] Data Feed) ⁴	
1.2	U.S. 75 HOV Lane Volume	Bethany Dr	Midpark Rd	5-min	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)	
1.3	Intersection Volume	Northern boundary of corridor	Southern boundary of corridor	Every 3 years	Historical	October 2014	Cities within the corridor	When new counts become available (Dr. Poe / Dr. Ardekani to provide)	
1.4	Ramp Volume	Highway 121	South Terminus in Dallas	5-, 15- or 60-min, if available; or historical data	April 2012 or historical	October 2014 or historical	TxDOT	Monthly or when available (Dr. Poe / Dr. Ardekani to provide)	
2.1	U.S. 75 GP Lane Speed	Highway 121	South terminus in Dallas	5-min	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)	
2.2	U.S. 75 HOV Lane Speed	Bethany Dr	Midpark Rd	5-min	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)	
2.3	Arterial/Frontage Road Travel Time	Greenville Ave and Coit Rd	Greenville Ave and Coit Rd	5-min	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)	
3.1	U.S. 75 Geometry (number of lanes by segment, distance between ramps, and detector locations)	Highway 121	South Terminus in Dallas	n/a	n/a	n/a	TxDOT	April 2012 (Dr. Poe / Dr. Ardekani to provide)	

Table 2-2. Quantitative Data Summary

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

⁴ It has been agreed with the Dallas site team that the University of Maryland (UMD)—a member of the national evaluation team—will receive a direct feed of various ICM system data, including the Public XML Feed as well as feeds from the Evaluation Subsystem (1.1.2), C2C, TxDOT, and DART Data Portal. This data will be available to the entire evaluation team from UMD.

	Data Element	Location		Data Collection	Data Collection Period ³		Data Collection	Data Transmittal
		Start	End	Frequency	Start	End	Responsible Party	
3.2	Arterials/Frontage Roads Geometry (number of lanes by link and link lengths)	Northern boundary of corridor	Southern boundary of corridor	n/a	n/a	n/a	Cities within the corridor	April 2012 (Dr. Poe / Dr. Ardekani to provide)
4.1	Average Vehicle Occupancy	n/a	n/a	n/a	n/a	n/a	NCTCOG	April 2012 and when an update is available (Dr. Poe / Dr. Ardekani to provide)
4.2	Vehicle Occupancy in HOV Lanes	Bethany Dr	Midpark Rd	Quarterly	April 2012	October 2014	DART	Quarterly (Dr. Poe / Dr. Ardekani to provide)
5.1	HOV Violation Rate	Bethany Dr	Midpark Rd	Quarterly	April 2012	October 2014	DART	Quarterly (Dr. Poe / Dr. Ardekani to provide)
6.1	LRT Passenger Count	Northern boundary of corridor	Southern boundary of corridor	By station and route, and for each time an LRT stops at a station	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)
6.2	LRT AVL Data	Northern boundary of corridor	Southern boundary of corridor	1-min, for each LRT train	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)
6.3	LRT Schedule and Adherence	Northern boundary of corridor	Southern boundary of corridor	By run	April 2012	October 2014	ICMS Data Feed; DART	Continuous for Schedule Data (UMD Data Feed); Monthly for Adherence Data (Dr. Poe / Dr. Ardekani
7.1	Parking Lot Locations and Capacities	Northern boundary of corridor	Southern boundary of corridor	n/a	April 2012	October 2014	DART	April 2012 and when updates are available (Dr. Poe / Dr. Ardekani to provide)
7.2	Parking Lot Utilization	Northern boundary of corridor	Southern boundary of corridor	Daily	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)

Table 2-2. Quantitative Data Summary (Continued)

	Data Element	Location		Data Collection	Data Collection Period ³		Data Collection	Data Transmittal
		Start	End	Frequency	Start	End	Responsible Party	
8.1	Log of Maintenance Activities ⁵	Northern boundary of corridor	Southern boundary of corridor	Daily	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)
8.2	Log of Construction Activities ⁶	Northern boundary of corridor	Southern boundary of corridor	Daily	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)
9.1	Incident Records	Northern boundary of corridor	Southern boundary of corridor	By incident	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)
9.2	Weather Information Records	Northern boundary of corridor	Southern boundary of corridor	Daily, and hourly during severe weather events	April 2012	October 2014	ICMS Data Feed; National Evaluation Team	Continuous (UMD Data Feed); Alerts from National Weather Service
9.3	Log of Special Events	Within the region	Within the region	By event	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)
10.	AMS Data (see specifics in Section 2.2.10)	Northern boundary of corridor	Southern boundary of corridor	Hourly during selected events (i.e., incidents, severe weather events, planned special events)	April 2012	October 2014	TTI, SMU, and AMS Contractor	As needed (AMS Contractor)
11.1	Traffic Volume on I-35E	n/a	n/a	Hourly	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)
11.2	Traffic Speed on I-35E	n/a	n/a	Hourly	April 2012	October 2014	ICMS Data Feed	Continuous (UMD Data Feed)

Table 2-2. Quantitative Data Summary (Continued)

⁵ See discussion in Section 2.2.8. As test plan implementation occurs, the availability and transmittal mechanism for <u>actual</u> maintenance and construction activities will be further discussed with the Dallas site team.

⁶ See discussion in Section 2.2.8. As test plan implementation occurs, the availability and transmittal mechanism for <u>actual</u> maintenance and construction activities will be further discussed with the Dallas site team.

Data Element	Location		Data Collection Data Collecti Period ³		ollection iod ³	Data Collection	Data Transmittal	
	Start	End	Frequency	Start	End	Responsible Party		
12.1 Ridership Data on other LRT Lines	n/a	n/a	Daily	April 2012	October 2014	DART	Monthly (Dr. Poe / Dr. Ardekani to provide)	
13.1 Notification of Occurrence of Candidate Event Case Studies	Northern boundary of corridor	Southern boundary of corridor	Daily, as they occur	April 2012	October 2014	TxDOT	Within 72 hours of event (E-mail to Ming-Shiun Lee (URS))	

Table 2-2. Quantitative Data Summary (Continued)

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2.2.1 Traffic Volume

Traffic volumes on U.S. 75 general purpose and HOV lanes will be collected by TxDOT detector stations. TxDOT's detectors provide good coverage on the U.S. 75 segments to be analyzed. Traffic data is collected in real time by each detector on a lane-by-lane basis. Data for all lanes is then aggregated and reported in five minute intervals to a central DalTrans database and to SmartNET via the C2C feed on a continuous basis, 24 hours a day, 7 days a week and throughout the entire evaluation period. In addition to volume, these detectors also measure speed, lane occupancy, and vehicle classifications. The national evaluation team will obtain the data via the SmartNET data feed.

The Dallas site currently does not have automated traffic counting capabilities on arterials and frontage roads. Cities within the corridor perform turning movement counts on signalized intersections along arterials and frontage roads once every three years. Historical turning movement counts will be available to the national evaluation team from individual agencies managing arterials.

The Dallas site does not have automated traffic collection capabilities on ramps along the U.S. 75 Corridor. To compensate the data gaps, the national evaluation team will use the detector data from U.S. 75 mainlines to extrapolate the number of vehicles entering and exiting the freeway at each interchange along the corridor. If historical counts at ramp locations are available, the national evaluation team will gather the information to assist in estimating ramp volumes. Turning movement counts at nearby intersections will also be taken into account in the extrapolation of ramp volumes.

2.2.2 Traffic Speed and Travel Time

TxDOT detectors collect speed data of U.S. 75 general purpose and HOV lanes on a lane-by-lane basis. Data is collected continuously from these detectors. Data for all lanes is aggregated and transmitted to DalTrans and SmartNET. The national evaluation team will obtain the data via the SmartNET data feed on a monthly basis.

Bluetooth readers are being installed and will collect travel time data on strategic arterials and frontage roads. Figure 2-3 shows the locations of the Bluetooth readers. Bluetooth readers will collect data on a continuous basis, 24 hours a day, 7 days a week, and throughout the entire evaluation period. Data collected via Bluetooth readers will be transmitted to SmartNET for the national evaluation team to access.

2.2.3 Roadway Geometry

The length and number of lanes for each link or segment of the roadway are necessary to compute the total volume, average speed, and subsequently travel time, delay, throughput and travel time reliability. In addition, the locations of traffic detectors (including Bluetooth readers) and on- and off-ramps are equally important to the Mobility Analysis. NCTCOG serves as the GIS coordinator for the 16-county region and has a GIS database that will provide roadway geometry information necessary for the national evaluation team to perform such computations at the beginning of the pre-deployment evaluation period.

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Figure 2-3. Bluetooth Reader Locations

2.2.4 Vehicle Occupancy Rate

Average vehicle occupancy rate is the average number of persons that occupy vehicles in each vehicle class of interest (e.g., automobiles, carpools, transit, etc.). For U.S. 75 general purpose lanes, arterials and frontage roads, the national evaluation team will use the average vehicle occupancy (AVO) rate for automobiles for the region that is provided by the NCTCOG. The decision to use the regional AVO rate is due to lack of a corridor-specific rate. AVO rates are traditionally estimated through labor intensive field data collection or surveys. Due to resource constraints, traditional methods for collecting and estimating AVO rate for the corridor are deemed infeasible. Using the regional AVO rate is the best available option, and based on the inputs from the Dallas site the regional AVO rate provides a valid representation for the corridor. The current AVO rate for the region is 1.14 persons per vehicle. These regional AVO data are collected on an ad hoc basis; the evaluation will use whatever most recent data is available.

DART collects vehicle occupancy data for HOV lanes on a quarterly basis. The primary source for transit vehicle occupancy will be automatic passenger counters (APCs). LRT Red Line currently has about 50 percent coverage in automatically collecting passenger counts. However, 100 percent of the Red Line LRT vehicles will be equipped with APCs sometime in 2013 as a result of the Transit Vehicle Real-Time Data Demonstration Project. APC and AVL data will be collected on a continuous basis. The national evaluation team will obtain APC data from DART on a monthly basis, while AVL data will be obtained via the SmartNET data feed.

2.2.5 HOV Violation Rate

HOV violation rates are observed through manual data collection. This manual data observation is conducted quarterly by DART. DART also maintains historical data on violation rates. Historical data will be obtained from DART at the beginning of the pre-deployment data collection period. Data collected during the evaluation period will be obtained from DART on a quarterly basis. HOV violation rates will be used to adjust person throughput measures on HOV lanes. That is, HOV violations (single occupant vehicles using the HOV lane) will be subtracted from the initial throughput calculation which assumes every vehicle using the HOV lane has multiple occupants.

2.2.6 Transit Data

Data required from transit services includes ridership, transit vehicle locations, schedule, and performance data for LRT Red Line. As discussed in Section 2.2.4, LRT Red Line has APCs on LRT vehicles to collect passenger counts. Transit vehicle location data is important to determine travel time and on-time performance for the transit service. Currently, all LRT vehicles are equipped with AVL. Actual transit performance based on the AVL data will be used to compare against the published schedule to determine on-time performance. Transit schedules and AVL data will be available for the national evaluation team via the SmartNET data feed. Transit APC data and on-time performance reports will be obtained through DART. All above data will be obtained on a monthly basis.

2.2.7 Parking Capacity and Utilization

The Dallas site team has preliminarily indicated that they do not believe that there will be any need to carry out their original proposed ICM strategy pertaining to temporary use of commercial property parking lots during times of high LRT demand. They base that on a recent study they did that indicated that sufficient parking capacity exists at their park & ride lots. However, as of the time of this test plan publication, a final decision on use of temporary, overflow parking has not been reached by U.S. DOT and the Dallas site team. The evaluation currently does not include consideration of temporary parking but will be adjusted as necessary when additional information regarding the final disposition of this strategy becomes available.

Information regarding locations and capacities of park & ride lots along the LRT Red Line is available from DART. DART currently has the information posted on its web site (http://www.dart.org/maps/locationslist.asp). Table 2-3 summarizes the park & ride lots and their capacities along the LRT Red Line within the corridor. DART will collect and provide to the national evaluation team if and when additions to the existing parking capacities are made available.

Station	Address	Capacity (Space)
Parker Road	2600 Archerwood St., Plano	2078
Bush Turnpike	1300 East President George Bush Turnpike, Richardson	1193
Arapaho Center	1051 N. Greenville Ave., Richardson	1100
Spring Valley	100 W. Spring Valley Road, Richardson	393
Lyndon B. Johnson Freeway (LBJ)/Central	8800 Markville Dr, Dallas	553
Forest Lane	8210 Forest Lane, Dallas	271
Walnut Hill	8150 Walnut Hill Lane, Dallas	170
Park Lane	8169 Park Lane, Dallas	1152
Mockingbird	5466 E. Mockingbird Lane, Dallas	735

Table 2-3. LRT Red Line Park & Ride Lot Locations and Capacities

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DART also collects information on utilization of park & ride lots. Parking utilization data at parking facilities at five of the Red Line LRT stations will be collected automatically via the Parking Management Information System. This system is expected to be operational in April 2012. Parking lot utilization data will be available for the national evaluation team via the SmartNET data feed.

2.2.8 Maintenance and Construction Activities

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

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

Schedule of pre-planned construction and maintenance activities are recorded by the Dallas site. The Dallas site team has indicated that they do not have readily-available information on what activities actually took place when and where. The Dallas site team has proposed that the national evaluation team derive that information by comparing dynamic message sign (DMS) text message logs against the planned activities list and, where they differ, assume that the DMS log accurately captured the activities as conducted (the Dallas site team has indicated that all construction and maintenance activities are included in DMS messages). The national evaluation team has not identified an automated approach to doing that comparison and lacks the resources to perform this cross-checking manually. Therefore, the current plan is to rely upon the log of pre-planned activities. The national evaluation team will continue to work with the Dallas site team as this test plan is implemented to attempt to identify a cost-feasible, reliable method to document actual maintenance and construction carried out in the field.

2.2.9 Events – Incidents, Severe Weather Events and Special Events

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

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

Snow and freezing rain is not uncommon in the Dallas area during the winter season. The area also experiences a fair share of severe thunderstorms with spectacular lightning shows, torrents of rain, and hail in the spring. For those reasons, the national evaluation team will focus the evaluation of severe weather event scenarios on snow/freezing rain and severe thunderstorm events. The national evaluation team will watch out for weather alerts issued by the National Weather Service. Weather alert information from the National Weather Service will also be stored in SmartNET. In addition to proactively observing and tracking weather events, the national evaluation team will review the data that will be obtained from SmartNET on a monthly basis to confirm all severe weather events are recorded. Once a weather event is identified as

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warranted for further investigation, the national evaluation team will gather the following information from the National Weather Service for evaluation: type of event (i.e., snow/ice event, thunderstorms), date and time of the event, duration, event details (e.g., amount of precipitation), areas of impact, impacts and reported damages if any.

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

2.2.10 AMS Model Results

It is not feasible to calculate person- or trip-based MOEs without a comprehensive set of field/empirical data. Due to gaps in field data, results from the AMS model will be used to assist in evaluating person- or trip-based MOEs. It is recognized that while the simulation results may not be appropriate for evaluating mobility MOEs at link or segment levels, the AMS model is adequate for producing reasonable results at network and corridor levels as well as for individual O-D trips. The application of AMS model results is particularly useful for evaluating personand trip-based throughput for arterials and frontage roads. Data needed for such an evaluation includes arterial/frontage road network volume and throughput measures for the entire corridor and for trips between a set of O-D pairs for both pre- and post-deployment periods for normal daily operations and selected scenarios including:

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

Specifically, the following AMS outputs will be required:

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

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

The national evaluation team is aware that the AMS model for the Dallas site is capable of producing acceptable results for scenarios involving major and minor incidents. The AMS model, however, does not currently have the ability to simulate corridor performance for scenarios involving server weather events and planned special events. The AMS model has been calibrated to simulate thirteen operational conditions, represented by combinations of low, medium, and high demand conditions under no incident and different severity of freeway incidents on U.S. 75 southbound at either Beltline Road or Forest Lane. The national evaluation team assumes that, in Stage 3B of the AMS effort, recalibration and validation of the AMS model will cover similar combinations of operational conditions as it was performed previously.

Whether the AMS model will be able to simulate weather and planned special event scenarios is still unknown at this point. In an event that the AMS model cannot produce adequate simulation outputs related to weather and planned special event scenarios, the national evaluation team will analyze and document selected MOEs based on data availability. Such MOEs will likely include mobility measures (volume, speed/travel time, throughput, and trip reliability) of U.S. 75 and LRT; and travel time and trip reliability of strategic arterials where Bluetooth readers are installed.

AMS model results will be provided to the national evaluation team by the AMS Contractor, Cambridge Systematics. Modeling results for normal daily conditions will be provided to the national evaluation team during the first 6 months of the pre- and post-deployment periods. Results for selected capacity reduction events (e.g., major and minor incidents, planned special events if available) will be provided by the AMS Contractor to the national evaluation within 2 months after receiving field data on each of those events by the national evaluation team and the Dallas site.

2.2.11 Traffic Data from I-35E Corridor

There are many "exogenous factors" that influence whether intended outcomes are realized and/or whether they can be measured and attributed to the ICM investment. Exogenous factors are further discussed in Section 2.4.6. Changes in travel demand and patterns in the corridor between evaluation periods are some of the exogenous factors that will have an impact on overall corridor performance. Traffic volume and speed/travel time data from other freeway corridors within the Dallas area will be used to compare against data from freeway detectors in the U.S. 75 Corridor to determine if overall travel demand and patterns have changed significantly between the pre- and post-deployment periods.

In collaboration with the Dallas site team and the U.S. DOT, I-35E is identified as the corridor for the purpose of evaluating exogenous factors. I-35E is a north-south corridor west of the U.S. 75 Corridor and is instrumented with adequate roadway detectors to collect traffic volume and speed data. Traffic data from I-35E will be collected by TxDOT using roadway detection systems. Data will be transmitted to the SmartNET and made available to the national evaluation team. The national evaluation team will obtain the data from SmartNET data feed.

2.2.12 Ridership Data from Other LRT Lines

Similar to traffic data from other freeway corridors in the region, ridership data on other LRT lines outside of the U.S. 75 Corridor will be compared to ridership of LRT Red Line to determine if travel demand and patterns in the corridor have changed dramatically between the evaluation periods. DART collects LRT ridership using APCs that are installed on LRT vehicles. While the entire LRT fleet servicing outside of the U.S. 75 Corridor may not be instrumented with APCs, DART utilizes samples to estimate total LRT ridership. Daily ridership data from other LRT lines will be obtained from DART on a monthly basis.

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2.2.13 Notification of Occurrence of Candidate Event Case Studies

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

2.3 Qualitative Data

No qualitative data elements are currently required for use in the mobility portion of the Corridor Performance Analysis Test Plan.

2.4 Data Analysis

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

2.4.1 Hypothesis Testing

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

Table 2-4. Mobility Analysis Hypotheses, MOEs and Testing Methods

Hypothesis	MOE Category	Testing Method
Overall Mobility Hypotheses		
The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor vehicle and person throughput	Throughput	Section 2.4.5.3
The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to improved corridor travel time and travel time reliability	Travel time, Travel time reliability	Section 2.4.5.1, Section 2.4.5.4
The combined impact of the ICM deployment overall will help balance network capacity and demand (load balancing), thus contributing to reduced delay on various roads and transit routes	Delay	Section 2.4.5.2
Strategy-Specific Hypotheses		
Dissemination of en-route traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput	Throughput	Section 2.4.5.3
Dissemination of en-route traveler information will encourage route shifts and result in increased corridor vehicle and person throughput	Throughput	Section 2.4.5.3
Provision of pre-trip traveler information will encourage modal shifts and contribute to increased transit ridership and improved corridor person throughput	Throughput	Section 2.4.5.3
Provision of pre-trip traveler information will encourage route shifts and result in increased corridor vehicle and person throughput	Throughput	Section 2.4.5.3
Coordination of traffic signals will reduce overall delay, improve travel time and travel time reliability and increase throughput	Travel time, Delay, Throughput, Travel time reliability	Section 2.4.5.1, Section 2.4.5.2, Section 2.4.5.3, Section 2.4.5.4
Strategy-Specific Hypotheses (Continued)		
Implementation of incident timing plans during incidents will reduce overall delay and improve travel time, throughput, and travel time reliability	Travel time, Delay, Throughput	Section 2.4.5.1, Section 2.4.5.2, Section 2.4.5.3
Temporary LRT capacity added in real-time during major incidents and/or unusually high demand periods will be utilized by travelers and thus contribute to improved person throughput.	Throughput	Section 2.4.5.3

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2.4.2 Data Aggregation

To compute the mobility performance measures, the national evaluation team will aggregate data spatially and temporally.

2.4.2.1 Spatial Aggregation of Roadway Detector Data

U.S. 75 Detector Data

The national evaluation team will start with the data that is available at the lowest level in SmartNET, which is data aggregated from all lanes at each detector station by direction. Data from the HOV lanes will be kept separate from general-purpose lanes.

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Detector station data will then be converted to link-level data. At this level, a "zone of influence" will be assigned for each detector station. This zone of influence will be equivalent to one-half the distance to the nearest upstream and downstream detector stations. Link travel times will be computed by applying the average detector station speed over the zone of influence for each detector station. Vehicle volumes will be subtotaled and multiplied by link length to estimate VMT for each link.

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

Arterial and Frontage Road Travel Time Data

Travel time data on strategic arterials will be collected using Bluetooth technology. Depending on the spacing of Bluetooth readers, data may represent link- or segment-level travel times. The same vehicle trajectory method for U.S. 75 data will be applied for data aggregation and to determine segment travel times.

2.4.2.2 Temporal Aggregation of Roadway Detector Data

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

2.4.3 Typical and Atypical Conditions

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

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2.4.3.1 Daily Operations

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

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

In addition, the national evaluation team will compute peak period performance measures. For the purpose of this evaluation, morning and afternoon peak periods are defined to be from 6:30 a.m. to 9:00 a.m. and from 3:00 p.m. to 7:00 p.m., respectively. The national evaluation team will work with the Dallas site team to adjust the definitions of peak periods as appropriate.

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

2.4.3.2 Atypical Conditions

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

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frequently during the course of the evaluation. As such, the atypical conditions to be analyzed will include major and minor incidents, severe weather events, and planned special events.

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

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

As described in Section 2.1.3.2, it will be important that the Dallas site team alerts the national evaluation within 72 hours of a candidate "event case study" occurrence so that special, ad hoc data collection associated with other evaluation analyses—e.g., the "pulse" traveler surveys included in the Traveler Response Analysis—can be initiated within a few days. The national evaluation team will provide the Dallas site team with a "watch list" of the types of events that are to be reported to the national evaluation team. Development of that watch list will entail a "cluster analysis" of historic incident data to identify frequency and patterns of incidents, if any, in the corridor and number of "hot spots" that are prone to incidents. This cluster analysis will help identify locations for the national evaluation team to focus on finding matching incidents. More importantly, the analysis will allow the national evaluation team to identify the types of incidents that have a higher possibility of reoccurring. Execution of this cluster analysis depends upon historic incident data to be provided by the Dallas site team.

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

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2.4.4 Evaluation of ICM Strategies

In addition to determine the collective contribution of ICM strategies, 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. The evaluation will employ the following techniques in an attempt to determine impacts of individual strategies or groups of strategies on corridor mobility performance.

- Utilization of Traveler Survey Data: The national evaluation team will draw upon the data collected through traveler surveys that will be conducted as part of the Traveler Response Analysis to better understand what aspects of an individual strategy or a group of individual ICM strategies led to what sorts of traveler responses. The national evaluation team will compare the field data with the survey responses to investigate the causal effect to determine the effectiveness of the strategy or strategies in changing travelers' behavior. For instance, during a major freeway incident that has been targeted for through the cluster analysis, information regarding the incident and potential delay due to the incident was disseminated to the public via 511 as well as roadside DMS's. In addition, messages to promote route- and mode-shifts were disseminated to both pre-trip and en-route traveler information devices. The pulse surveys will ask travelers if they received disseminated information and the effect of such information to their travel decisions. The survey results will provide an indication as to which strategies actually caused people to make a travel decision and change travel behavior. The national evaluation team will also analyze the traffic and transit data from the field to observe the mobility performance during the incident to understand the effect of changes in travelers' behavior on corridor operations. The combined results of the mobility analysis and traveler response analysis can provide useful information to understand the impacts and contributions of individual strategies or groups of strategies on corridor performance.
- Comparative Scenario Analysis: If it happens that there are any examples where different response plans are implemented in response to two or more separate incidents or conditions which are very similar, this could provide an opportunity to assess the impact of the different strategies. It is far from certain whether there will be opportunities of this sort, but there are a couple of reasons that different responses could be implemented for essentially equivalent circumstances. For example, it could be that later in the post-deployment period, based on previous unsatisfactory experience with response X, the Dallas site team could shift to response Y. Or, it could be that refinements in the ICMS Expert Rules Subsystem and/or Prediction Subsystem over the course of the post-deployment period could result in changes in response plan application.
- Analysis of Phased-in Deployment: As discussed in Section 2.1.3.1, individual components of the deployment will be completed in a phased manner, with full ICM system operations currently scheduled to commence in January 2013. The Dallas site team has indicated that they do expect, to at least some degree, to begin using individual components and associated ICM strategies as they become available prior to the overall system go-live. This phased-in deployment approach may provide an opportunity to understand the impacts of individual strategies on corridor mobility performance. To the

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extent possible, the national evaluation team will isolate and separately analyze data that are impacted by phased-in deployments prior to the overall system go-live. The national evaluation team will perform a before-after comparison to determine how individual system components and strategies may have contributed to changes in mobility performance.

2.4.5 Performance Measure Calculation Procedures

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

- Auto-Non HOV Lanes: Traveling by private vehicle using arterial/frontage road segments or a combination of arterial/frontage road segments and U.S. 75 general purpose lanes.
- Auto-HOV Lanes: Traveling by private vehicle on roadway network with a portion of the trip on U.S. 75 HOV lane.
- Transit: This includes (1) exclusive transit trip, either taking LRT only or using a combination of LRT and local bus or feeder bus route(s); and (2) "kiss and ride" trips where travelers being dropped off at LRT stations and taking LRT to destination.
- Auto-Park &Ride-Transit: Driving and parking private vehicle at a LRT park & ride lot and taking LRT to destination.

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

2.4.5.1 Travel Time

Travel time (TT) for U.S. 75 general purpose and HOV lanes will be computed using the detector data from TxDOT. Link travel times will be computed by applying the average detector station speed over the zone of influence for each detector station. As discussed in Section 2.4.2, link-level data will be aggregated to the segment and corridor levels. Travel time data on strategic arterials will be collected using Bluetooth technology. The vehicle trajectory method described in Section 2.4.2 will be used for data aggregation and to determine segment travel times.

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

$$TT_{Transit} = TT_{Bus} + Mean Waiting Time + TT_{LRT}$$

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

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

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

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

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

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

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

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

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

2.4.5.2 Delay

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

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

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

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

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

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

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

$$Delay = VD + TVD$$

2.4.5.3 Throughput

Vehicle Throughput (VT) is a measure of the number of vehicles that are served in one direction of a facility during the analysis period. Vehicle throughput on each link of U.S. 75 general purpose and HOV lanes will be measured using TxDOT's detectors, while vehicle throughput on arterials and frontage roads will be estimated using historical and current traffic counts.

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

$$PT = VT \times AVO$$

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

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

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

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

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

VMT will be computed for U.S. 75 general purpose lanes and HOV lanes using TxDOT detector data. Due to lack of real-time data collection capabilities, VMT for arterials and frontage roads will be estimated using either historical and current traffic counts or the results from the AMS model. Specifically, historical and current traffic counts will be used as the basis for estimating volumes on arterials and frontage roads during normal daily operations. For atypical conditions, results of AMS model will be used for VMT estimation for arterials and frontage roads. AMS results may not provide sufficient details and accuracy at a link level. However, for the purpose of estimating VMT at segment and corridor levels and for particular O-D trips, it is expected the AMS model will provide representative results for VMT estimates.

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

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

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

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

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

Similar to VMT calculations, historical and current traffic counts with regional AVO rate will be used as the basis for estimating PMT on arterials and frontage roads during normal daily operations. Results from AMS model will be used for PMT estimation for arterials and frontage roads for atypical conditions.

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

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

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

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

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

2.4.5.4 Travel Time Reliability

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

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

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

Free-flow speeds for arterials and frontage roads will be derived using the travel time data from Bluetooth readers. Arterial/frontage road free-flow speeds will be 85th percentile speeds and will be computed similar to that for freeway free-flow speeds. The national evaluation team will analyze historical volume data for arterials and frontage roads to determine low-volume periods for deriving free-flow speeds.

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

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

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

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

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

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

Percentiles of travel time will be computed using the field data directly.

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

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

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

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

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

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

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

$$s^{2} = \frac{\sum (TT \text{ of ith } Trip - Mean \, TT)^{2}}{n-1}$$

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

2.4.6 Exogenous Factors

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

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

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

In addition, data from freeway detectors and LRT Red Line passenger counts within the corridor will be compared to data from I-35E and other LRT lines outside the corridor to determine if overall travel demand and patterns in the corridor have changed dramatically between evaluation periods. If traffic demand and patterns appear to have shifted radically, the national evaluation team will use a trend analysis to examine how factors such as changes in unemployment rates, gas prices, and land-use development have impacted travel conditions between the pre- and post-deployment periods.

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

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

Table 2-5 summarizes the national evaluation team's approach to control and understand the impact of exogenous factors.

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

Table 2-5. Methods to Control Exogenous Factors

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2.4.7 Application of the Logic Model

Overall conclusions regarding corridor mobility performance will be based on consideration of not only the results associated with each of the MOEs collected and analyzed through this test plan but will also take into consideration the "input" (ICM investments), "output" (Agency practices and technology), and "tier 1 outcome" (traveler information awareness) findings that will be gleaned from throughout the evaluation, especially the Institutional and Organizational, Technical Capability, and Traveler Response Analyses. For example, in any cases where it may be found that the Dallas ICM system did not generated the expected corridor performance

outcomes, these findings will be compared against the documentation of ICM investments to understand the extent to whether and how the investments were made influenced the ultimate generation of outcomes, or lack thereof. That is, this analysis will seek to understand why the various outcome results were observed and that will include consideration of the inputs (investments), outputs (technology), and/or tire 1 outcome (awareness of traveler information).

In this way, this mobility and other evaluation analyses will utilize the inherent power of the logic model to help explain findings (e.g., whether they are related to ICM or not and the specifics ICM strategies to which they are related) based on the overall pattern of findings along the length of the logic model. Table 2-6 illustrates, at a conceptual level, this notion of how specific combinations of input, output and outcome findings from across the logic model and from across the evaluation can aid in understanding various ICM strategies as well as understanding the potential influence of exogenous factors.

	Eva	luation Res	ults	Outcome Linked		
Strategy	Input	Output	Outcome	Only to this Strategy?	Conclusion	
А	+	+	+	Yes	Strategy responsible for all ICM- related impacts but exogenous factors may also have contributed	
В	-	-	+	Yes	ICM not responsible for impact because investment not made; exogenous factors responsible for outcomes	
С	+	+	-	No	ICM not responsible for impact because practices and technologies did not translate to traveler behavior and/or capacity changes OR exogenous factors obscured impact	
D	+	+	+	No	Strategy responsible for at least some impacts (other strategies and/or exogenous factors also possible)	

Table 2-6. Interpreting Results from Across the Logic Model

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2.5 Risks and Mitigations

Successful evaluation of the mobility performance is dependent on the completeness and comprehensiveness of data from the site. While it appears that most of the data required to do the analysis will be available, there are some areas of gaps and uncertainty which in turn pose challenges and risks to the analysis. Table 2-7 identifies the risks associated with this analysis and the national evaluation team's response plan for each risk.

	Risk	Mitigation Strategy
1.	Lack of automated traffic volume counts on arterials and frontage roads. Volume counts on arterials and frontage roads are performed annually using tube counters. The annual counts typically cover one-third (1/3) of the arterial roadways within the corridor. The counts represent normal daily operations and do not support traffic diversion and/or modal shifts due to incidents and events.	The national evaluation team will use the counts with necessary adjustments (such as traffic growth, shifts in peak periods) to represent normal daily operation conditions. AMS modeling capability will be used to support analyzing volume-related MOEs (such as throughput and other vehicle- and person- weighted measures) during atypical conditions. Traveler survey will also be used to supplement and validate AMS results for atypical conditions.
2.	Matching of comparable incidents or events occurring at the same location during the same period of the time.	If no comparable incidents can be found and matched during pre- and post-deployment periods, the national evaluation team will look for incidents that may closely resemble the targeted incident and document the differences between the incidents and key assumptions used, and explain how various factors (such as differences in operating conditions, ICM strategies used, etc.) may be attributable to the results.
3.	Phased-in ICM system deployment creates challenges to baseline data collection. Current site schedule indicates that the first set of ICM components that will have direct impact on corridor mobility performance will be tested and accepted as early as April 2012. Assuming the deployed components will be operational immediately after acceptance, it will leave the evaluation with approximately 3 to 4 months of untainted baseline data.	The national evaluation team will use the untainted data from the 3-month period to represent the "true" baseline conditions. If necessary, the national evaluation team will go back 4 to 9 months to obtain historical data for supplemental data collection. It is expected historical data on key data elements including freeway volume and speed data, and transit data will be available. The national evaluation team will compare untainted with tainted data and draw on traveler survey data to gain understanding of the impact of phased-in system deployment. The national evaluation team will also isolate and separately analyze data from areas impacted by phased-in deployments during the pre-ICM period to evaluate the impact of individual deployments on mobility performance.
4.	Faulty or failing data collection technology during evaluation period. A possibility exists that some data collection devices (such as roadway detectors, Bluetooth readers, AVL, automatic passenger counters, etc.) will become inoperable during the evaluation period.	If and when data collection devices fail, the national evaluation team will perform internal range checks and observe time series patterns to detect faulty data. Faulty data will be excluded from the analysis.

Table 2-7. Risks and Mitigations

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3.0 SAFETY ANALYSIS

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

3.1 Analysis Overview

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

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

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Figure 3-1. Overview of Safety Analysis

U.S. DOT has identified a single, broad hypothesis related to ICM safety impacts:

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

The broad hypothesis suggests two overall assessments that might reasonably be made: 1) assessing an overall lack of harm for the ICM implementation, and 2) demonstrating one potential mechanism (i.e., reduction of secondary crashes) by which the ICM implementation may improve safety. While the second evaluation is conceptually possible, the national evaluation team has judged that there are not appropriate data and resources available to complete it. Instead, only the first aspect of the hypothesis will be examined in this test plan. The overview of the subject safety analysis is shown graphically in Figure 3-1.

Overall ICM Safety Hypotheses:

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

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

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analysis are the same multi-hour peak periods evaluated in the remainder of the mobility analysis.

Table 3-1 identifies the specific data and MOE that will be used to test the evaluation hypothesis, including several data elements/MOE previously discussed in Chapter 2. The particulars of the crash data element (element 3)—which is not collected through the mobility analysis—are elaborated in Section 3.2. The overall design of this analysis includes simple data summaries by geographic location of accidents before and after the ICM deployment, and a corresponding general log-linear model of crash count data with corresponding estimation of the rate of accidents after ICM deployment compared to before.

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

Table 3-1.	Safety	Analysis	s Data,	MOE,	and	Hypothesi	is
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* These data elements (or, in the case of Vehicle Miles Traveled, MOE) will be available from the mobility portion of the Corridor Performance Analysis.

3.2 Quantitative Data

This chapter identifies the quantitative data elements to be used in the safety portion of the Corridor Performance Analysis. Those data elements include several data elements and one MOE (VMT) that will be collected and utilized in the mobility portion of the Corridor Performance Analysis described in Chapter 2: VMT, maintenance and construction activity, and incident, weather, and special events. Table 3-2 presents the additional data element required for this safety analysis: crash data. The crash data element is discussed following Table 3-2.

Data Element	Location		Data Collection	Data Collection Period		Data Collection Responsible	Data Transmittal
	Start	End	Frequency	Start	End	Party	
3.1 CRIS Data	Within the region	Within the region	By crash	Apr 2012	October 2014	TxDOT	Monthly (TxDOT will send to National Evaluation Team)

Table 3-2. Quantitative Data Summary

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3.2.1 CRIS Data

Traffic accident data are expected to be available through the TxDOT Crash Records Information System (CRIS). TxDOT collects and analyzes crash data submitted by law enforcement on form CR-3, Texas Peace Officer's Crash Report, and by those outside law enforcement on form CR-2. Such reports are required in Texas for any crash involving injury or death, or causing at least \$1,000 of property damage. As such, it is likely that very minor crashes are excluded from the data. Hence, it must be interpreted that in addition to other limitations, the safety analysis conclusions only apply to reported crashes causing property damage or involving injury.

Simplified versions of the database records are available to the public to include date and time of crash, number of vehicles involved, and location of the crash. These records are available for the current calendar year and for the previous five years. The CRIS data will be treated as a comprehensive list of crashes for the evaluation time periods. To facilitate the calculation of the safety MOE, the following data is needed:

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

It is assumed that the national evaluation team will be able to work directly with TxDOT to obtain data extracts from CRIS that provide the additional level of detail of the geocoded location, and the time of the crash, which do not appear to be available from the public data. Note that the crash time is a recorded field on the reporting forms. The location can be entered as latitude and longitude coordinates in the CR-3, but also may be provided only as a roadway and nearest cross road. It is unknown if the geocoding is available within CRIS at this time.

3.3 Qualitative Data

No qualitative data elements are currently required for use in the safety portion of the Corridor Performance Analysis Test Plan.
3.4 Data Analysis

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

3.4.1 Hypothesis Testing

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

3.4.2 Data Aggregation

To compute the safety performance measures, crash data records will need to be geocoded to a location and include date and time information. The geocoded data can then be attributed to a corridor segment and to one of three types of roadways in the corridor; U.S. 75 general purpose lanes, U.S. 75 HOV lanes, and arterial or frontage roads. Crash data records in the form of counts of vehicles will be associated with a corresponding number of vehicle miles traveled for a particular time period and segment. The definition of segments and of VMT are provided in the mobility chapter.

The time period for the evaluation will be the pre-deployment baseline period of November 2011 to November 2012, and the post-deployment period of May 2013 to May 2014. Each period represents one calendar year, so it is assumed that the two time periods are adequately representative of seasonal variability that might occur in crash data.

3.4.3 Typical and Atypical Conditions

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

Note that there is a legitimate hypothesis that safety could be impacted by ICM deployment during atypical conditions. However, the only way that this could fairly be evaluated in a pre and post-deployment scenario would be to identify a set of atypical conditions occurring in both time periods that were sufficiently similar so as to provide a strong probability that the observed

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safety differences in the two periods might be attributed to the ICM deployment condition and not be confounded with the safety characteristics of the events themselves. It is judged that this assumption is too onerous to expect to actually occur.

3.4.4 Statistical Modeling

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

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

3.4.5 Descriptive Statistics and Data Summaries

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

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

3.4.6 Statistical Modeling and Testing of Hypotheses

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

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

U.S. Department of Transportation, Research and Innovative Technology Administration Intelligent Transportation System Joint Program Office The vehicle data will be evaluated using count models. A standard statistical model for count data posits that under certain conditions, counts (for instance the number of crashes on a particular road segment over a period of time) may follow a Poisson distribution. Consequently, the crash data will first be fit to such a model. The model will include the predictor variables as well as an offset for the VMT (log transformed). Model diagnostics will be examined to determine the goodness of fit for this model. Models of this type of data frequently must be adjusted at the least to account for overdispersion. This means that the data show variability, likely due to additional unmeasured factors not accounted for by the subset of factors evaluated in the model. In this case, an overdispersion effect will be included in the model.

If the Poisson model is not entirely reasonable, a separate negative binomial model will also be assessed. The negative binomial model naturally accounts for overdispersion relative to the Poisson model. If each observed data element is consistent with an observation from an underlying Poisson distribution, but the underlying Poisson distributions vary from data point to data point as a Gamma distribution, the entire process may be modeled as a negative binomial distribution. This may be reasonable in the case of the crash data if the Poisson distribution of counts of accidents varies from day to day, perhaps based on a large number of unmeasured factors relating to the behaviors and dispositions of the drivers on the roads.

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

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

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

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

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3.5 Risks and Mitigations

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

	Risk	Mitigation Strategy
1.	Lack of automated traffic volume counts on arterials and frontage roads. Volume counts on arterials and frontage roads are performed annually using tube counters. The annual counts typically cover one-third (1/3) of the arterial roadways within the corridor. The counts represent normal daily operations and do not support traffic diversion and/or modal shifts due to incidents and events.	The national evaluation team will use the counts with necessary adjustments (such as traffic growth, shifts in peak periods) to represent normal daily operation conditions.
2.	Crash data reporting will lag real time so that the post-deployment year's data will not be available in time to complete the evaluation.	The calendar months of crash data that are available in the post-deployment period will be compared only to the same calendar months in the pre-deployment baseline period. Alternatively, if ICMS feed logs can provide more timely crash data with equal quality and level of detail, these data may supplement that of the crash data reporting system.
3.	Crash data will not be available with time of day.	All crash data within the date window, regardless of time of day, will be analyzed. This will reduce the sensitivity of the analysis compared to the peak hour model planned. Additionally, all accident data for any day with an exceptional event will be removed, not just the records within the impacted time window.
4.	Crash data will not be available with geocoding.	If the number of records is not too large, a manual coding effort could be undertaken, but this would require additional resources beyond those planned. Alternatively, data could be subset only at the grossest geographic level (e.g., county) with corresponding loss of specificity in modeling parameters.
5.	The CRIS incident records may not be adequately complete (due to lack of content or latency in posting) to perform the planned analysis.	The ICM system logs may provide an alternate source of crash data.

Table 3-3. Risks and Mitigations

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