

Integrated Corridor Management

Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas

Post-Deployment Analysis Plan

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16. Abstract <p>Post-Deployment Analysis, Modeling, and Simulation (AMS) activities focus on identifying impacts and benefits of the “as-deployed” Integrated Corridor Management (ICM) system. The “as-deployed” ICM strategies may differ from “as-planned” ICM strategies. The differences could include ICM strategies that are not successfully deployed, ICM strategies that are deployed differently from planned because of technical issues, and ICM strategies that are deployed differently to take advantage of enhancements or impacts not anticipated before deployment. Further, Post-Deployment AMS activities take full advantage of site-specific traveler behavior and response characterization efforts conducted by the Volpe Center and the ICM Evaluation contractor activities included in the post-deployment efforts. The objective of the Post-Deployment AMS efforts is to ensure that the models and methodologies can sufficiently replicate and evaluate corridor conditions and the proposed ICM strategies after ICM deployment. In this stage, the AMS contractor and the Demonstration site staff will confirm, refine, and validate the parameters/assumptions that serve as the basis for the ICM strategies in these models. These updated and enhanced models and methodologies can provide further insight on ICM implementation and other operational benefits that will help guide the demonstration projects, future ICM deployments, as well as assist in the evaluation activities.</p> <p>This Post-Deployment Analysis Plan for the U.S.-75 Corridor outlines the various tasks associated with the application of the ICM AMS tools and strategies to this corridor in order to support the post-deployment analysis and demonstration of the proposed ICM system, and assist in the evaluation effort.</p>					
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Chapter 1. Introduction and Project Scope

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

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

The focus of this ICM Post-Deployment assessment is to evaluate to what extent ICM technologies can efficiently and proactively manage the movement of goods and people in a major transportation corridor. Specifically, this project will investigate the impacts of the ICM system in its “as deployed” state on U.S.-75 in Dallas, using analysis, modeling, and simulation (AMS) tools and techniques developed and refined under both the current and previous phases of the program. Results from traveler behavior surveys conducted in the vicinity of the U.S.-75 corridor by the Volpe Center will be used to inform model assumptions and to enable more accurate representation of true driver behaviors on U.S.-75. The results of the post-deployment AMS will then be used to assess and validate the estimated impacts from the predeployment analysis.

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

- Develop a post-deployment AMS Plan in collaboration with the ICM Demonstration Site staff to promote coordination of analysis efforts and coherent alignment of goals among this effort, the ICM Demonstration Site staff, and the ICM Evaluation team.
- Support the objective evaluation efforts of the Demonstration Site staff and enhance the ability of the modeling tools to accurately represent the deployed ICM strategies by identifying and facilitating improvements to AMS tools, techniques, and inputs.

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

This post-deployment analysis builds upon previous work that was completed under the predeployment AMS project (U.S. Department of Transportation (DOT) Contract DTFH61-06-D-00004), which examined the potential benefits of ICM on U.S.-75 in Dallas prior to its realization in 2013. The predeployment analysis provided a detailed measure of expected impacts according to the planned design of the ICM project on U.S.-75 prior to its deployment. Among the products from that predeployment analysis relevant to this current project are:

- An AMS Plan specifically tailored to the unique characteristics and conditions of the U.S.-75 corridor.
- A baseline simulation model of the ICM corridor capturing all major roadways and transit facilities within the study area, calibrated and validated to state-of-the-art standards.
- An alternatives analysis methodology and application that enabled the comparison of several performance metrics of the U.S.-75 corridor under various scenarios with and without ICM.

Work products associated with the predeployment analysis will be essential to the timely preparation of the tools and data needed for the current post-deployment analysis given the schedule constraints of the current contract. Consequently, the products from the predeployment analysis of U.S.-75 in Dallas remain relevant to this current post-deployment analysis, and several references will be made throughout this document to the predeployment analysis. These references will be accompanied by summaries of procedures, models, methodologies, and outcomes, as appropriate, with the finer points available in the source document if more detail is desired. (*Final Pre-Deployment Analysis Plan: Stage 3A Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas*. Cambridge Systematics, Inc., for U.S. DOT. December 2011.)

This ***Post-Deployment Analysis Plan for the U.S.-75 Corridor*** outlines the core tasks associated with the realization of the project goals and objectives described earlier. The organization of this analysis plan is as follows:

- **Chapter 2** provides a brief description of the U.S.-75 Corridor in Dallas, Texas.
- **Chapter 3** describes the ICM strategies comprising the ICM deployment on the corridor.
- **Chapter 4** describes the AMS methodology.
- **Chapter 5** describes the performance measures use in the AMS.
- **Chapter 6** provides guidance for model calibration.
- **Chapter 7** describes the AMS approach and related tasks.
- **Chapter 8** provides the schedule and resource guide for the post-deployment AMS tasks.

Chapter 2. U.S.-75 Corridor Description

The U.S.-75 Corridor is a major north-south radial corridor connecting downtown Dallas with many of the suburbs and cities north of Dallas. The U.S.-75 Corridor has been defined at two levels. The immediate corridor consists of the freeway, a light-rail line, and arterial streets within approximately two miles of the freeway. In addition, a full “travel shed” influence area has been defined that includes additional alternate modes and routes that may be affected by a major incident or event. The travel shed area is generally bound by downtown Dallas to the south, the Dallas North Tollway to the west, State Highway (SH) 121 to the north, and a combination of arterials streets and Dallas Area Rapid Transit (DART) Blue Line to the east, for an approximate corridor length of 28 miles. (Source: Concept of Operations for the U.S.-75 Integrated Corridor, Dallas, Texas, March 2008.)

U.S.-75 is Dallas’ first major freeway, completed around 1950, and fully reconstructed with cantilevered frontage roads over the depressed freeway section and reopened in 1999 with a minimum of eight general purpose lanes. The freeway mainlines carry more than 250,000 vehicles a day, with another 20,000 to 30,000 on the frontage roads.

The U.S.-75 Corridor study area includes the freeway, continuous frontage roads, light-rail line, transit bus service, park-and-ride lots, major regional arterial streets, toll roads, bike trails, and intelligent transportation systems. A concurrent-flow, high-occupancy vehicle (HOV) lane in the corridor opened in December 2007.

The corridor study area also contains the first light-rail line, the Red Line, constructed in Dallas, part of the 20-mile DART starter system, opened in 1996. The Red Line now expands into the Cities of Richardson and Plano, and passes next to the Cities of Highland Park and University Park. This facility operates partially at-grade and partially grade separated through deep-bored tunnels under U.S.-75. In addition, the Blue Line operates near downtown Dallas, and extends along the eastern edge of the corridor boundary. The Orange Line extends from Dallas-Fort Worth to downtown Dallas. Finally, in downtown Dallas, the light-rail lines connect to the regional commuter-rail line, the Trinity Express.

The U.S.-75 Corridor study area serves: 1) commuting trips into downtown Dallas, via the freeway, bus routes, light-rail line, and arterial streets; 2) a significant number of reverse commuters traveling to commercial and retail developments in the northern cities and neighborhoods; 3) regional traffic during off-peak periods; and 4) interstate traffic into Oklahoma, since the freeway is a continuation of Interstate 45. The corridor also is a major evacuation route and experienced significant volumes during the Hurricane Rita evacuation in 2005.

There are three major freeway interchanges in the corridor study area. In the southern section, U.S.-75 has an interchange with the downtown freeway network connecting to Interstate 45 and Interstate 35E. At midpoint there is a newly constructed interchange with Interstate 635, while in the northern section, there is an interchange with the President George Bush Turnpike (PGBT). Figure 1 illustrates the U.S.-75 Corridor, with the primary corridor study area highlighted, and the roadways included in the study area.

Chapter 3. Integrated Corridor Management Strategies

Note: The contents of this chapter have been based on the “Operations and Maintenance Plan for the U.S.-75 ICM, Dallas Integrated Corridor Management (ICM) Demonstration Project” developed by the Dallas Area Rapid Transit (DART) and dated January 3, 2014.

The purpose of the U.S.-75 ICM project is to implement a system and organizational structure that will provide for the operation of the Corridor in a multimodal, integrated, efficient, and safe fashion. The ICM concept represents a shift for management and operations within the Corridor—from the current partial coordinated operations between corridor networks and agencies, to a fully integrated and proactive operational approach that focuses on a corridor perspective rather than a collection of individual networks.

Agencies within the corridor already have taken actions to manage the transportation network and reduce congestion. The U.S.-75 Integrated Corridor Management Project will build upon these capabilities. Using cross—network operational strategies, the agencies will capitalize on integrated network operations to manage the total capacity and demand of the system in real time in response to changing corridor conditions. With improved traveler information the public will be able to shift trip mode, route and time of day based on current conditions. New transportation operations and management systems will allow agencies to better monitor current conditions and use capacity more efficiently. Strategies available to be implemented as part of the ICM project include:

- Providing improved multimodal traveler information.
- Develop preapproved response plans among agencies.
- Divert traffic to key frontage roads and arterials with responsive traffic signal control.
- Shifting travelers to transit during major incidents on the freeway.

The U.S.-75 ICM project includes the implementation of a number of technology systems and elements including:

- A **Decision Support System** (DSS) that monitors real-time data to assess current transportation network conditions, recommends preapproved strategies and response plans when events occur that affect corridor operations, analyzes and predicts response plan benefits, and evaluates response plan results.
- A **SmartNET Subsystem** which provides a graphical user interface that supports multiagency input and information sharing related to the transportation network including incidents, construction, and special events as well as the current status of devices and performance of the roadway and transit networks. It also is the means for communicating and monitoring response plans.

- **A SmartFusion Subsystem** which provides data collection, processing, fusion and dissemination functions for the system.
- A number of supporting projects and activities deployed in support of ICM such as a DART parking management system, traffic responsive signal control on key diversion arterials in the Cities of Richardson, and Plano and a regional 511 traveler information system.
- ICM operations are expected to be decentralized with the DalTrans Transportation Management Center (TMC) serving as the corridor’s central coordination point. Field systems are expected to be operated by local agencies in accordance with ongoing agency operating capabilities, resources and procedures. In addition, there is a dedicated ICM Coordinator for the corridor, who job is to review and accept appropriate Response Plans that are recommended by the DSS for review by local agency operators, insure the corridor agencies are responding to requests, and monitor the overall performance of the corridor.

The systems involved in ICM operations fall into two categories:

- **Integrated Corridor Management System (ICMS):** These are the technical systems that make up the ICMS, including SmartNET, Smart Fusion and DSS.
- **Agency Operations Systems:** These are agency systems that provide or support field operations needed to implement ICMS strategies and response plans, collect systems data, etc.

Figure 2 shows the major system components.

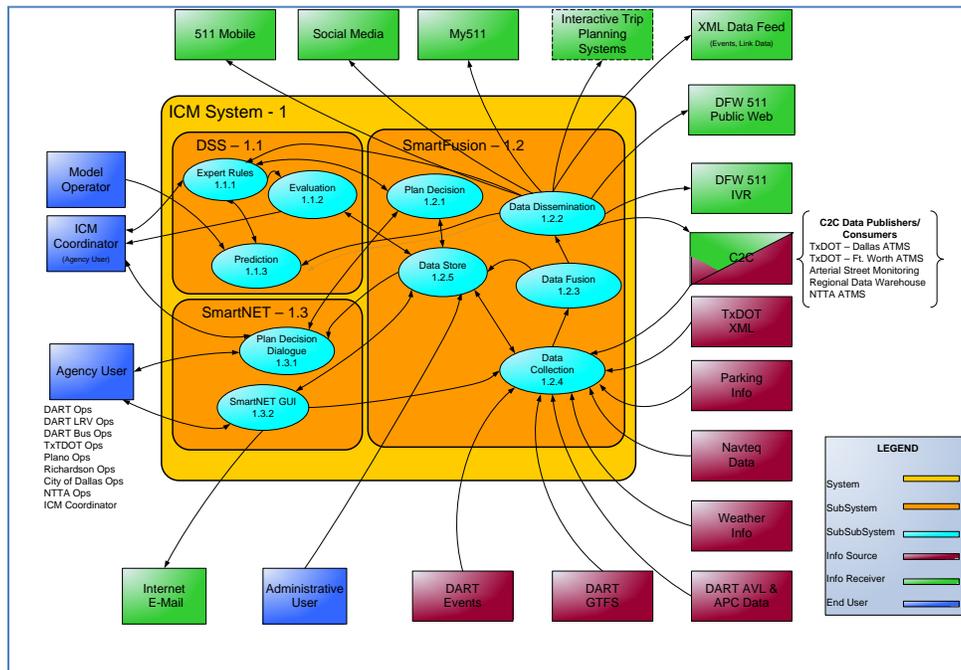


Figure 2. Diagram. High-level U.S.-75 Integrated Corridor Management System conceptual diagram.

(Source: Dallas Area Rapid Transit, January 3, 2014.)

The U.S.-75 ICM project is a collaborative effort led by 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).

The Dallas ICM deployment focuses on four ICM goals, including improve incident management, enable intermodal travel decisions, increase corridor throughput, and improve travel-time reliability. ICM strategies to achieve these goals include:

- Provide comparative travel times between various points of interest to the public via the 511 system for the freeway, strategic arterial streets, and light-rail transit line, as well as real-time and planned events status and weather conditions.
- Use simulations to predict travel conditions for improved operational response.
- Implement interdependent response plans among agencies.
- Encourage traffic diversion to parallel arterials and frontage roads with improved, event-specific traffic signal timing response plans.
- Encourage shift of travelers to the light-rail system during major incidents on the freeway.

Chapter 4. Analysis, Modeling, and Simulation Methodology

The modeling approach used in the U.S.-75 Corridor project is an integrated platform that can support corridor management planning, design, and operations by combining the capabilities of existing tools. The overall integrated approach is based on interfacing travel demand models and mesoscopic simulation models. Within the U.S.-75 corridor, the Analysis, Modeling and Simulation (AMS) methodology includes the macroscopic trip table manipulation for the determination of overall trip patterns, and mesoscopic analysis of the impact of traveler behavior in reaction to Integrated Corridor Management (ICM) strategies (both within and between modes).

Modeling Components

The following paragraphs provide an overview of the various modeling components utilized in the AMS modeling framework for the U.S.-75 Corridor.

Travel Demand Forecasting Model

Travel demand models estimate demand based on projections of household and employment characteristics and predict preferences in activity location, time of day, mode, and route choice. The North Central Texas Council of Governments (NCTCOG), Dallas' metropolitan planning organization (MPO), maintains the regional travel demand model in TransCAD. The static nature of NCTCOG's travel demand model is not entirely compatible with the dynamic nature of travel choices during an incident situation. Dynamic Intermodal Routing Environment for Control and Telematics (DIRECT), the selected mesoscopic model for the U.S.-75 Corridor study area, models the diversion to different routes or modes during simulation run time, thus circumventing the need to feed back to the travel demand model and providing a more realistic view of the traveler decisions and their impact to network conditions.

The NCTCOG model will be used as the primary source for the vehicular trip tables and networks. Available coefficients (e.g., value of time, operating cost per mile, etc.) and variables from the travel demand model were reviewed and adjusted for incorporation into the to the generalized cost equation within the simulation model. While travel demand subarea procedures allowed for the extraction of the vehicular demand for the U.S.-75 Corridor study area, similar procedures were not available for the transit component. Therefore, the Dallas AMS team utilized the Dallas Area Rapid Transit (DART) onboard survey to develop an estimate of the transit origin-destination (OD) trip table.

Mesoscopic Simulation Model

Mesoscopic models combine properties of both microscopic and macroscopic simulation models. Similar to microscopic models, the mesoscopic model's unit of traffic flow is the individual vehicle. The movements in a mesoscopic model, however, follow the approach of macroscopic models and are

generally governed by the average speed on the travel link. Mesoscopic models provide less fidelity than microsimulation models, but are superior to travel demand models, in that they can evaluate dynamic traveler diversions in large-scale networks.

For the analysis of the U.S.-75 Corridor, the mesoscopic model DIRECT developed by the Southern Methodist University (SMU) was used. DIRECT supports the analysis of the dynamic impact of ICM strategies, such as route shifts, mode shifts, and corridor-specific traveler information (pretrip and en-route). Figure 3 shows the model network used in post-deployment AMS.

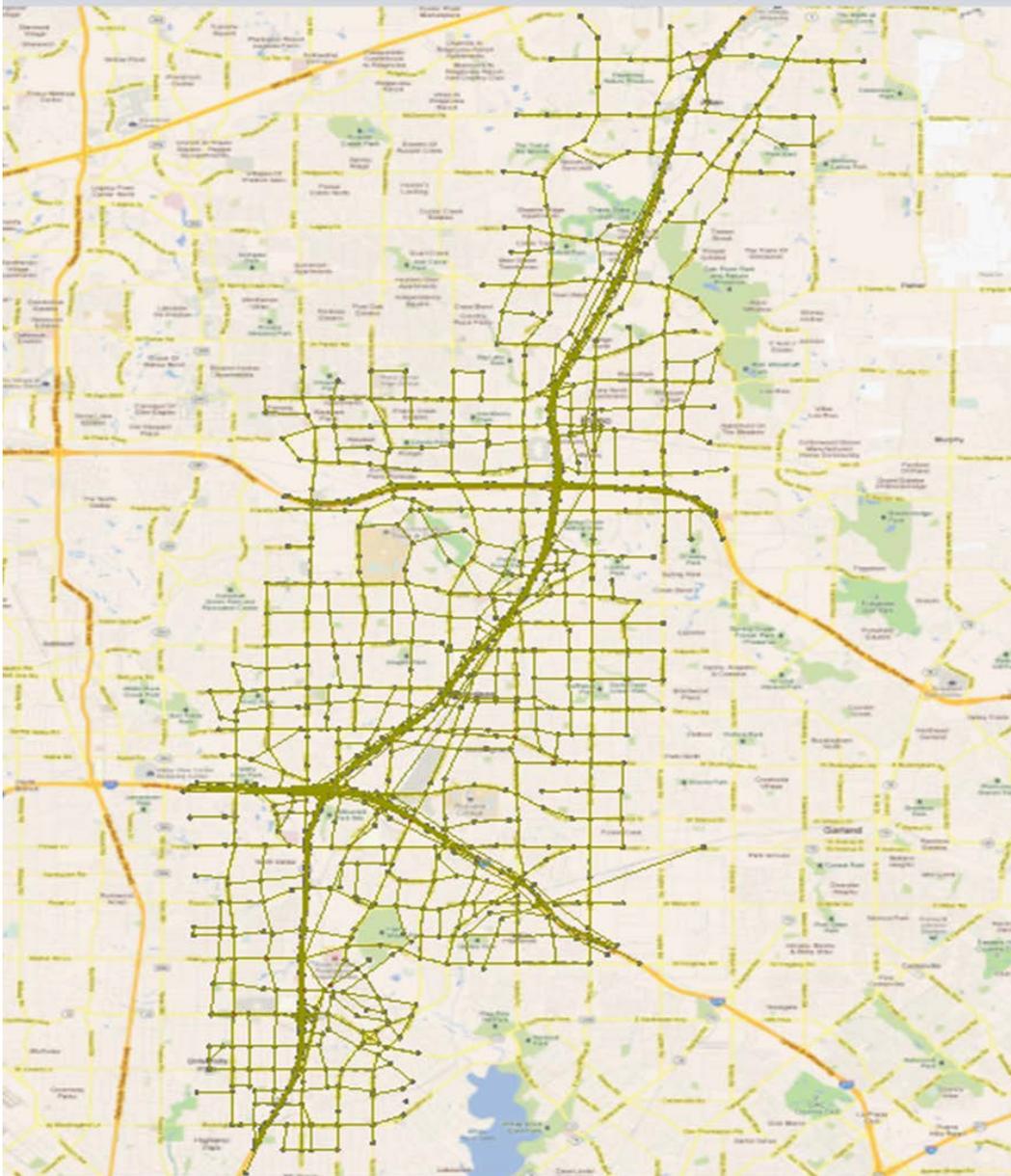


Figure 3. Map. Model network U.S.-75 for Post-Deployment Analysis, Modeling, and Simulation.

(Source: Cambridge Systematics, Inc.)

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Intelligent Transportation Systems Joint Program Office

In DIRECT, the traveler's mode and route are generated so that each traveler is assigned to a route-mode option that: 1) minimizes the traveler's generalized cost; and 2) matches the traveler's mode preference options which are influenced by the willingness to car pool and to use transit.

As part of the model input, each origin-destination pair is assigned a value to represent the percentage of travelers who are willing to use transit (i.e., considering transit in their mode choice set either as pure mode or combined with private car) or carpool. An estimate of the willingness to use transit was obtained as the ratio between the number of transit travelers recorded in the DART onboard transit survey and the total number of travelers estimated for each origin-destination pair.

Each origin-destination pair also is assigned a value to represent the percentage of travelers who are willing to carpool. The regional demand model provides information on the number of carpooling travelers who use the high-occupancy vehicle (HOV) facility, and number of carpooling travelers who do not use any HOV facility. As an estimate of the willingness to carpool, for an origin-destination pair, the sum of HOV and non-HOV users was first multiplied by the average car occupancy, and then divided by the total number of travelers for this pair. An average car occupancy of two persons per vehicle was assumed. Based on the DART survey, the average willingness to use transit was estimated at 44 percent. For origin-destination pairs that the DART survey did not provide estimates for, the willingness to use transit was set at 4 percent. Based on these estimates and the regional model data, the average transit and carpool willingness were 5.8 and 21.5 percent, respectively.

Based on the willingness to use transit or carpool of a traveler, the following four sets of mode-route options are evaluated at five-minute intervals:

- Set I—Routes for Single-Occupancy Vehicles, or SOVs (drive-alone).
- Set II—Routes for HOVs (carpool).
- Set III—Routes for park-and-ride (excluding carpool).
- Set IV—Routes for transit (pure transit).

For example, if the traveler is not willing to use transit and not willing to carpool, then the traveler will choose a route from set I. On the other hand, if the traveler is willing to use transit and not willing to carpool, then the traveler will choose from sets I, III, or IV. Another case could be that the traveler is not willing to use transit but is willing to carpool, then the traveler will choose from sets I or II.

For each traveler willing to carpool, a search for another traveler is made. This other traveler must satisfy the following conditions:

- Departing from the same origin zone.
- Departing within a given time window (10 minutes).
- Going to the same destination zone.
- Willing to car pool.

This search is repeated until a maximum of four travelers is reached (i.e., capacity of the private car). If a match is found, this vehicle is marked as HOV, and the route set that includes the HOV facilities is made available as part of the choice set (sets I and II). If a match is not found, the HOV route options are excluded and the other options are made available (sets I, III, and IV). Currently, DIRECT does not

model a drive-carpool option. As such, all travelers that are eligible to carpool are starting from the same origin node.

The travelers' mode and route choice is done simultaneously and is a function of the congestion evolution in the network. DIRECT utilizes a multiobjective shortest path algorithm coupled with an incremental all-or-nothing, rather than a dynamic user equilibrium, assignment. Travel times along a route are reflective of the link travel times when the traveler is generated (instantaneous travel times), rather than the link travel times at the time the traveler enters the link (experienced travel times). DIRECT loads each traveler to the shortest vehicular, transit, or park-and-ride path, calculated every five minutes.

The value of time and the travel and transit costs reflect global values based on NCTCOG's travel demand model documentation (1999 dollars). These values were adjusted during the calibration of the DIRECT model to reflect the nature of travel within the U.S.-75 Corridor study area.

Based on this process, the actual number of travelers that use transit or carpool depends on the relative value of the generalized cost of the four potential mode-route options: drive alone (SOV), carpool (HOV), park-and-ride, and pure transit (with and without transfers). As such, in a scenario where the transit and carpool willingness may remain the same, the number of travelers that uses transit or carpool also could change.

At the end of the process, information on each generated traveler is saved in a text file (called the travelers file) describing the trip start time (loading time in the simulation) and the chosen mode and route. These mode-route choices reflect choices established over the long-term under normal (including recurring congestion) traffic conditions and are identified as "historical routes."

Initial runs in DIRECT were completed for each demand condition to establish a static population of travelers from the demand inputs from the NCTCOG demand model which were then used for each of the scenario runs. Each generated traveler is assigned a set of attributes, which includes his/her trip starting time, generation link, final destination, and a distinct identification number. In parallel, transit vehicles are generated according to a predetermined timetable and follow predetermined routes. Prevailing travel times on each link are estimated using the vehicle simulation component, which moves vehicles while capturing the interaction between autos and transit vehicles. DIRECT also utilizes other measures that may be used by travelers as criteria to evaluate the different mode-route options, including highway tolls, private car operation cost, transit fares, and out of vehicle time.

These measures, along with travel time, are combined in a generalized cost formula utilized in a mode-route decision module activated at fixed intervals to provide travelers with a set of mode-route options. Travelers evaluate the different mode-route options and choose a preferred one. Based on the available options, a traveler may choose a "pure" mode or a combination of modes to reach his/her final destination.

If a traveler chooses private car for the whole trip or part of it, a car is generated and moved into the network with a starting time equal to its driver starting time. Each newly generated vehicle is assigned an ID number that is unique to this vehicle. Vehicles are then moved in the network subject to the prevailing traffic conditions until they reach their final destinations or the next transfer node along the prespecified route (in the case of an intermodal trip).

If a traveler chooses a transit mode, he/she is assigned to a transit line such that the destination of this traveler is a node along the route followed by the bus line. If no single line is found or if the traveler is not satisfied with the available single line, the traveler is assigned to a path composed of two lines with one transfer node, such that the destination of the traveler is a node along the route followed by the second bus. When a transit vehicle arrives at a certain stop, all travelers waiting for a vehicle serving this specific line board this vehicle and head toward either their final destination or the next transfer node along their route.

Upon the arrival of a vehicle (private car or transit vehicle) to a certain destination node, this destination is compared to the final destinations of the travelers onboard. If it matches the final destination of a traveler, the current time is recorded for this traveler as his/her arrival time. If they are different, the traveler transfers to the next transit line in his/her plan. The nearest stop is again determined and the traveler waits for his/her next transit vehicle. This process is continued until all travelers reach their final respective destinations.

Route and mode choices in the U.S.-75 Corridor are influenced by adverse traffic conditions (e.g., incidents or heavy demand) or ICM strategies (such as traveler information systems). The integrated mode-route choice in DIRECT utilizes a generalized cost function to support comparison of multimodal alternatives. For example, travelers may choose to use transit instead of their vehicle, if they receive information before their departure from home and the transit option is more attractive (i.e., the generalized cost is lower). Alternatively, if they receive en-route information of an incident, they may decide to park their car at the nearest park-and-ride lot and switch to transit. Finally, they may choose to continue driving if they receive en-route information of an incident, and they are either close to their destination or it is determined that driving to the nearest park-and-ride lot would significantly increase their generalized cost.

During an incident, travelers follow their long-term established mode-route choices (“historical routes”) unless they encounter freeway/arterial congestion or receive and consider pretrip or en-route information that may identify a more attractive mode-route option compared to the “historical route.” Pretrip information could be in the form of a TV announcement, an email alert, or information provided by a Web site. En-route information could be in the form of a radio announcement, a dynamic message sign (DMS), or live traffic updates via a Global Positioning System (GPS) receiver.

During an ICM strategy assessment, travelers are loaded from the pertinent traveler file, which includes information related to the trip start time (loading time in the simulation) and their “historical route.” In addition, as part of the model input, travelers are associated with three mutually exclusive groups based on their degree of access to information: 1) no information (group A); 2) pretrip information (group B); and 3) en-route information (group C).

Travelers with no-information follow their “historical routes.” Travelers with pretrip information have the option to update their routes and/or mode of transportation at the origin of their trips. Travelers with access to en-route information could receive updates through their devices at any node along their routes, including their trip origin. Therefore, a portion of them could be considered as travelers with access to pretrip information as well. As such, for modeling purposes, group B considers travelers with access to pretrip information ONLY, while group C considers travelers that have access to pretrip, as well as en-route information.

In addition to the above, travelers on a freeway or arterial link consider changing their route if they perceive that they have encountered severe congestion, where severe congestion is defined as the

density of either of the two links downstream of the vehicle's current position exceeding 80 percent of the link's jam density. These travelers are picked randomly among groups A, B, and C and constitute group R.

Finally, any traveler associated with groups A, B, or C could pass a DMS and be eligible to respond to the available information. As such, travelers passing a DMS constitute group DMS. In the deployed Dallas ICM system, DMSs are activated if a response plan calls for their activation and stay activated until termination of the response plan.

The following paragraphs provide an overview of the diversion rules for each traveler group. It should be noted that travel times associated with "nonhistorical routes" are based on instantaneous travel times—these are travel times at the instance that travel-time information is provided to travelers.

- **DMS Diversion**—This type of diversion is only applicable to travelers in group DMS. DMSs are only activated if they are part of a coordinated response plan and only from the time the response plan is implemented to termination of the plan. Travelers responding to a DMS compare the generalized cost of the updated route, from the downstream node of the current link to the final destination, with the generalized cost of the corresponding section of the originally assigned route. Diversion occurs only if the generalized cost savings between the updated and originally assigned route, compared to the generalized cost of the originally assigned route, is more than 10 percent.
- **Pretrip Diversion**—This type of diversion is applicable to travelers in group B. Travelers with access to pretrip information at their origin, compare the generalized cost of the suggested mode-route option to their destination with the generalized cost of their "historical route." Diversion occurs only if the generalized costs savings between the updated and originally assigned route, compared to the generalized cost of the originally assigned route, is more than 10 percent.
- **En-Route Diversion**—This type of diversion is applicable to travelers in group C. Travelers equipped to receive en-route information compare the generalized cost of the updated route, from the downstream node of the current link to the final destination, with the generalized cost of the corresponding section of the originally assigned route. Diversion occurs only if the generalized costs savings between the updated and originally assigned route (or drivers' perceptions of costs savings), compared to the generalized cost of the originally assigned route, is more than 10 percent. Paths of travelers in this group are recalculated at time of departure and at every intermediate node in the network. More specifically, the optimized path (based on the lowest generalized cost) is calculated every five minutes for every node to every destination (generation or intermediate node). When a traveler is generated, that path is assigned to the traveler. If the traveler is receiving en-route information (group C) a path from the downstream node to the destination is assigned from the latest optimized path calculation.
- **Congestion Diversion**—This type of diversion is only applicable to travelers in group R. When the congestion diversion is triggered, the shortest freeway or arterial path (based on travel time and the current interval shortest path calculation) initiating from the first downstream exit (ramp or intersection) is assigned to the traveler. As such, group R travelers' decisions are neither multimodal nor comparative.

The priority of compliance for route diversion is as follows: 1) DMS; then 2) en-route; and 3) congestion. For example, at a DMS location, if a traveler belongs to group C, group R, and group DMS, it is assumed that the traveler will follow the DMS diversion rule.

In order for DIRECT to account for traveler information and model the above diversion rules correctly, each traveler with pretrip or en-route information is associated with two parameters: awareness and use. Awareness indicates that a traveler has access to the information (pretrip or en-route), while use indicates that a traveler is willing to act based on the information. Willingness does not necessarily result in an action, unless the proposed mode-route option is more attractive than the “historical route,” based on the diversion rules discussed above. Therefore, use reflects an upper bound on the percent of travelers who might divert as a response to the information, with the actual percentage dependent on the attractiveness of the new route and referred to as “compliance.” As an example, if 20 percent of travelers have access to pretrip information (awareness) and of that subgroup, 15 percent are willing to act on that information (use), then the maximum compliance would be 3 percent of the total traveler population.

While DMS is a form of en-route information, it presents a special case in the current version of DIRECT, it is assumed that 100 percent of the travelers have access to the information presented in the DMS.

Modeling Integrated Corridor Management Strategies

The following list identifies the ICM strategies implemented as part of the U.S.-75 ICM system:

- Travel-time information (pretrip and en-route).
- Incident signal retiming plans for arterials.
- Incident signal retiming plans for frontage roads.
- Light-Rail Transit (LRT) information on parking availability.
- Red/Orange Line capacity increase.

The strategies listed above are discussed in more detail in the ensuing sections.

Traveler Information

Multimodal information dissemination includes travel-time comparisons for freeway, arterial, and transit to provide travelers with information on the best routes and modes. The information also includes park-and-ride availability. As a result, more travelers will be able to choose the best option (alter route, mode, and departure time) that reflects the optimal path. The travel time information is distributed pretrip and en-route. In post-deployment AMS the estimation of parameters related to awareness and use of traveler information in the U.S.-75 ICM corridor will be based on findings from the survey conducted by the Volpe Center. Assumptions used for these parameters in stage 2, predeployment AMS are listed below so as to enable comparisons between pre- and post-deployment AMS.

Pretrip Traveler Information

Pretrip information includes any traveler information accessible to the public that could be used in planning trip routes, estimating departure times, and/or choosing a travel mode. Such information can

be obtained through the agency Web sites, the 511 system, public access television (TV), local radio, and other media. The analysis must capture the impacts of such information on traveler's route choice, departure times, and/or choice of travel mode.

Based on the 2005 Perception Tracking survey conducted in Minneapolis, 61 percent of travelers were aware of pretrip information, and 15 percent made use of it. In stage 2 predeployment AMS and given that limited data existed on the percentage of U.S.-75 travelers who access such information and are willing to act on it (i.e., divert from their "historical routes") prior to making their trips, the Dallas AMS team utilized awareness and use values similar to the Minneapolis study, including 60 percent *awareness* and 10 percent *use* of pretrip information for the pre-ICM scenarios. Post ICM implementation, the Dallas AMS team expected *awareness* to increase as 511 and more valuable traveler information are deployed (as happened indeed), and used 80 percent *awareness* and 20 percent *use* of pretrip information for post-ICM scenarios. Travelers with pretrip information had the capability to update their routes only at the origin of their trips. As such, the generalized cost of the available mode-route options was calculated at the beginning of their trip, and if an option was more attractive compared to the "historical route," that option was selected.

Given the relationship in DIRECT of travelers with access to pretrip and en-route information (previously discussed), 10 percent (out of the 60 percent) in the predeployment AMS were considered travelers with access to pretrip information ONLY (group B). The remaining 50 percent reflected travelers that have access to en-route information also (group C). In the post-deployment AMS, the corresponding percentages are 20 and 60 percent for groups B and C, respectively.

En-Route Traveler Information

One of the U.S.-75 ICM strategies intends to proactively disseminate en-route information via 511, radio/TV, agency Internet sites, smart phones, etc. Discussions with U.S. Department of Transportation (DOT) and the Dallas AMS team revealed a need to model the impact of en-route information available to drivers to assess two major issues:

- **Change in Route Choice**—This relates to real-time change in route choice of drivers based on travel time or congestion updates they receive via radio, 511, GPS devices, or information provided by a DMS sign.
- **Change in Mode En-Route**—The possibility of changing mode while en-route has potential on the U.S.-75 Corridor, considering the availability of a number of park-and-ride facilities. An SOV traveler may receive en-route traveler information of congested conditions on U.S.-75 and park-and-ride availability at the stations along the DART Red or Orange lines. Proposed DMS message information is simple with incident information and recommendation to "Try DART light rail," while other media may provide more detail about the incident, actual number of park-and-ride lots spaces available, and comparative travel-time information.

En-route information is provided by either a DMS sign or traveler information media that can range from radio to GPS devices. The 2005 Minneapolis Perception Tracking survey indicated that 72 percent of the drivers have seen a sign (*awareness*), but only 29 percent alter their route based on the available information (*use*). For DMS analysis, in the predeployment AMS the Dallas AMS team utilized 60 and 75 percent awareness and a use of 20 and 30 percent for the pre-ICM and post-ICM scenarios, respectively. In the absence of data related to en-route traveler information media, the

Dallas team utilized 50 percent *awareness* and 20 percent *use* for the pre-ICM scenarios. For the post-ICM scenarios, *awareness* increased to 60 percent and *use* to 30 percent.

Table 1 provides a summary of modeling assumptions used in predeployment AMS regarding awareness, use, and compliance to pretrip and en-route traveler information for both pre- and post-ICM implementation. The contents in this table were refined based on the findings resulting from the traveler survey conducted by the Volpe Center in the U.S.-75 corridor.

Table 1. Modeling assumptions regarding awareness, use, and compliance to traveler information—U.S.-75 stage 2 Analysis, Modeling, and Simulation (Percent).

Traveler Information	Pre-ICM					Post-ICM				
	None	Pretrip	En-Route	Total	DMS	None	Pretrip	En-Route	Total	DMS
Awareness	40%	10% (+50%)= 60%	50%	100%	60%	20%	20% (+60%)= 80%	60%	100%	75%
Use		10%	20%		20%		20%	30%		30%
Compliance		1%	10%				4%	18%		

(Source: Cambridge Systematics, Inc.)

Note: “Use” does not necessarily result in an action, unless the proposed mode-route option is more attractive than the “historical route,” based on the diversion rules. Therefore, “use” reflects an upper bound on the percent of travelers who might divert as a response to the information, with the actual percentage dependent on the attractiveness of the new route and referred to as “compliance.”

Incident Signal Retimings

As part of the ICM deployment, the U.S.-75 ICM stakeholders developed ‘flush’ signal timing plans to increase arterial throughput and decrease arterial travel time during an incident. The increase in throughput will be reflected in DIRECT in the form of signal retiming. Generally, southbound or northbound phases had the green time increased to allow for more throughput along those routes.

Frontage Road Signal Retiming

For a minor incident, signal retiming adjustments may suffice on the frontage roads only. By giving more green time to the southbound or northbound movements on the frontage road, freeway travelers can detour to the frontage road upstream of an incident and return to the freeway downstream of the incident.

Arterial Street Signal Retiming/Coordination

In addition to the frontage road signal retiming, signal retiming and signal coordination to a strategic arterial may increase corridor throughput. The stakeholders identified Greenville Avenue as the

primary arterial for diverted freeway traffic, since it runs parallel to U.S.-75 for nearly the entire length of the freeway corridor, and it also is the closest major arterial with available capacity. This strategy generally included increasing green time to the southbound or northbound movements along Greenville Avenue and sometimes also along the frontage roads.

Parking Availability at Red Line Park-and-Ride Lots

For the mode shift strategies, parking at the Red Line LRT park-and-ride lots is critical to encourage changes in travelers' behavior. The DART park-and-ride lots toward the north end of the Red Line have been in past years at capacity, with station parking often taking place on adjacent city streets. However, DART recently expanded the Parker Road and the President George Bush Turnpike (PGBT) Stations, which will provide needed capacity for future ICM strategies.

The parking strategy was to implement Smart Parking systems at each of the DART park-and-ride lots on the Red Line along U.S.-75. This is a basic system that continuously collects vehicle counts entering and leaving the lot, and records the number of parking spots available. By disseminating information regarding park-and-ride lot availability, traveler's confidence in transit is expected to increase, and potential modal shifts may occur during incidents. Internet, TV, and radio information may include more detail about the actual number of park-and-ride lots spaces available at each station. With ICM and Smart Parking, DIRECT allows the lot to reach full capacity before the park-and-ride lot paths are excluded from the route and mode selection.

Red/Orange Line Capacity Increase

DART has the capability of adding capacity to the Red/Orange Lines through additional train cars or through decreased headways during the off-peak only. Under major corridor incidents, it may be beneficial to decrease headways of the Red/Orange Line to increase the person carrying capacity of the LRT system.

Table 2. Post-Deployment Analysis, Modeling, and Simulation assumptions and inputs.

Outcome of Strategies	Summary/Notes to Modeling Team	Without ICM	With ICM in Place
1. Traveler Information			
1.1 Higher percentage of travelers with access to incident and travel-time information	Because of better quality information and better integration between agency systems, traveler information systems will disseminate better incident and travel-time information to travelers. The effect is that more travelers will be able to alter routes, modes, and departure times. Incident duration stays the same with and without ICM.	Higher percentage of travelers with access to incident and travel-time information	Higher percentage of travelers with access to incident and travel-time information and higher percentage of travelers willing to make changes (based on Volpe survey findings).
1.2 Travel times (mode and route)	Information dissemination (pretrip and en-route) will include travel times for freeway, arterial, and transit. The effect is that more travelers will choose the best options to maintain consistent trip times.	Freeway mainline travel-time only	The decision choice is based on a generalized cost that feeds into a decision model. The effect is that, as conditions worsen, more travelers will take more alternative options including transit.
2. Improved Traffic Management			
2.1 Incident signal retiming plans for frontage roads and arterials	'Flush' signal timing plans to increase arterial throughput and decrease arterial travel-time during an incident.	Local, occupancy-based signal timing	Alternative algorithms and new signal timing plans created and customized to fit particular incident scenarios.
3. Improved Transit Management			
3.1 Smart parking at park-and-ride lots	By disseminating information regarding park-and-ride lot availability, traveler's confidence in transit is expected to increase, and potential modal shifts may occur during incidents.	No information on parking availability	DMS information will indicate "Try Transit." Internet, TV, and radio information may include more detail about the actual number of park-and-ride lots spaces available at each station.
3.2 Red Line capacity increase (during the off peak only)	DART has the capability of adding capacity to the Red/Orange Line through additional train cars or through decreased headways.	No additional DART capacity during major incidents	Under major corridor incidents and during the off peak, it may be beneficial to decrease headways of the Red/Orange Line to increase the person-carrying capacity of the LRT system.

(Source: Cambridge Systematics, Inc.)

Chapter 5. Performance Measures

This chapter provides an overview of the performance measures used in the Analysis, Modeling, and Simulation (AMS) of Integrated Corridor Management (ICM) strategies for the U.S.-75 Corridor. The performance measures focus on the following key areas.

Mobility

Mobility describes how well the corridor moves people and freight. The mobility performance measures are readily forecast. Three primary types of measures will be used to quantify mobility in the U.S.-75 Corridor, including:

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

Reliability and Variability of Travel Time

Reliability and variability capture the relative predictability of the public's travel time. Unlike mobility, which measures how many people are moving at what rate, the reliability/variability measures focus on how much mobility varies from day to day. Appendix B of the final report titled, *Integrated Corridor Management Analysis, Modeling, and Simulation for the U.S.-75 Corridor in Dallas, Texas*, describes the methodology that will be used in calculating reliability and variability impacts.

Emissions and Fuel Consumption

The U.S.-75 Corridor AMS also will produce model outputs for use by the Evaluation Contractor to estimate emissions and fuel consumption, associated with the deployment of ICM strategies. The emissions analysis methodology will incorporate reference values to identify the emissions and fuel consumption rates based on variables, such as facility type, vehicle mix, and travel speed. The

emissions and fuel consumption rates will be based on available sources. Emissions will be computed by pollutant, mode, and facility type. Fuel consumption will be computed by fuel type, mode, and facility type.

Cost Estimation

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

- **Capital costs**—Include up-front costs necessary to procure and install intelligent transportation system (ITS) equipment. These costs are shown as a total (one time) expenditure that includes the capital equipment costs, as well as the soft costs required for design and installation of the equipment.
- **Operations and Maintenance (O&M) costs**—Include those continuing costs necessary to operate and maintain the deployed equipment, including labor costs. While these costs do contain provisions for upkeep and replacement of minor components of the system, they do not contain provisions for wholesale replacement of the equipment when it reaches the end of its useful life. These O&M costs are presented as annual estimates.
- **Annualized costs**—Represent the average annual expenditure that would be expected in order to deploy, operate, and maintain the ICM improvement; and replace (or redeploy) the equipment as they reach the end of their useful life. Within this cost figure, the capital cost of the equipment is amortized over the anticipated life of each individual piece of equipment. This annualized figure is added with the reoccurring annual O&M cost to produce the annualized cost figure. This figure is particularly useful in estimating the long-term budgetary impacts of U.S.-75 corridor ICM deployments.

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

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

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

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

Chapter 6. Guidance for Model Calibration

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

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

Available data on bottleneck locations, traffic flows, and travel times will be used for calibrating the simulation model for the analysis of the U.S.-75 corridor. The U.S.-75 Corridor calibration strategy will be based on the three-step strategy recommended in the Federal Highway Administration (U.S. Department of Transportation) Guidelines for Applying Traffic Microsimulation Modeling Software Dowling, R., A. Skabardonis, and V. Alexiadis, *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*, U.S. DOT-HRT-04-040, Federal Highway Administration, July 2004):

- **Capacity calibration**—An initial calibration is performed to identify the values for the capacity adjustment parameters that cause the model to best reproduce observed traffic capacities in the field. A global calibration is first performed, followed by link-specific fine-tuning. The capacity calibration for the U.S.-75 Corridor will be performed utilizing volume data collected by Texas A&M Transportation Institute (TTI) on the corridor freeway, frontage roads and parallel arterials, and from the Texas Department of Transportation (TxDOT) database.
- **Route choice calibration**—Because the U.S.-75 corridor includes parallel arterial streets, route choice calibration plays a significant role in the overall calibration effort. After capacity calibration, this second calibration process is performed with the route choice parameters. A global calibration is first performed, followed by link-specific fine-tuning.
- **System performance calibration**—Finally, the overall model estimates of system performance (travel times and congestion patterns) is compared to the field measurements for travel times and congestion patterns. Fine-tuning adjustments are made to enable the model to better match the field measurements.

The calibration criteria presented in table 3 will be applied in all ICM analysis, modeling, and simulation (AMS).

Table 3. Model calibration criteria.

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

(Source: U.S. 75 Dallas, Texas, Analysis Plan, FHWA-JPO-10-035, p. 37.)

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

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

Chapter 7. Analysis, Modeling, and Simulation Approach

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

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

This chapter describes the post-deployment AMS activities that will support the ICM system for the U.S.-75 corridor. During post-deployment AMS, the tools and methodologies developed in previous AMS efforts will be revisited and further evaluated in order to improve the capability of the site-specific tools to represent and evaluate the ICM system. The key objectives of post-deployment AMS include the following:

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

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

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

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

This section describes the task items related to coordination and support of the alteration of tool inputs, analytical methodology, and enhancements to analytical software to reflect post-deployment corridor management technologies and strategies. The AMS team will coordinate with the U.S.-75 ICM team and the Evaluation team to confirm, refine, and validate the parameters and assumptions that serve as the basis for modeling traveler responses and impacts related to ICM strategies currently present in the models used in the real-time decision support efforts. Dallas Area Rapid Transit (DART) and local stakeholders will review the model parameter assumptions to ensure that they sufficiently capture travel characteristics for the corridor and system response times according to the capabilities of their transportation management systems.

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

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

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

If external factors impacting operational conditions in the corridor are significantly different post-ICM deployment (e.g., unusual weather patterns, dramatic changes in travel demand related to changed economic activity or fuel prices), which would require a level of effort beyond the envisioned

Reasonableness Assessment here, then the AMS team will develop an analysis plan to mitigate the impact of these external factors in support of the ICM Demonstration Evaluation.

The Reasonableness Assessment Methodology involves the comparison of the U.S.-75 model volumes and speeds (including bottleneck locations) with field observed data. In order to perform this assessment, the methodology includes four steps, as detailed in the following sections.

Step 1. Data Collection

The first step in the Reasonableness Assessment is to obtain the necessary data inputs, including field observed volumes and speeds along the freeway mainline and ramps of the U.S.-75 Corridor, and arterials in the overall corridor area. Such data are being collected and archived as part of the ICM deployment on U.S.-75 and as part of the evaluation effort.

Step 2. Reasonableness Assessment Criteria

The Reasonableness Assessment methodology will employ similar elements of the model calibration criteria detailed in the U.S. Department of Transportation (DOT) Guidelines for Applying Traffic Microsimulation Modeling Software, including two types of data comparisons:

1. **Volume comparison**—The first part of the assessment will determine whether the model reasonably replicates observed volume data both globally and for individual facilities. The criteria for comparing flows between model and observed values are summarized in table 4.
2. **Travel speeds and bottlenecks**—The reasonableness of the model’s speeds will be assessed based on a visual audit comparing speed contour diagrams from observed data with model speed data. Speed contour diagrams depict typical weekday speeds along the U.S.-75 Corridor during the peak periods.

Table 4. Reasonableness assessment criteria and acceptance targets.

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

(Source: U.S. 75 Dallas, Texas, Analysis Plan, FHWA-JPO-10-035, p. 37.)

Step 3. Model versus Observed Data Comparison

The third step of the Reasonableness Assessment will involve comparing the model outputs and performance measures against field volume and bottleneck data along the U.S.-75 Corridor. The

criteria established in step 2 will then be utilized to determine whether the model results adequately replicate the field data.

The reasonableness assessment of the Dynamic Intermodal Routing Environment for Control and Telematics (DIRECT) model's output includes a comparison of traffic volumes both by hour and globally. To fulfill the visual bottleneck audit criteria, the model output will be compared against the observed speed contours to assess whether the model output sufficiently replicates the temporal and geographical extents of bottlenecks along the corridor. Speed contour diagrams will be used to show that bottlenecks are occurring in approximately the same geographical location as on the field and that link speed-flow relationships, as well as queuing patterns appear to be reasonable in the model. These comparisons will be conducted for both the AM and PM peak periods, for both peak and off-peak directions, and for both a "typical day" and an incident day.

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

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

Step 4. Network and Demand Adjustments

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

Step 5. Summary of Results

The final step of the Reasonableness Assessment will be to summarize the methodology and results of the Reasonableness Assessment in a technical memorandum in a draft and final version. The technical memorandum is titled "Dallas U.S.-75—Post-Deployment Analysis, Modeling, and Simulation (AMS) Reasonableness Assessment and Tool Modification Technical Memorandum—Final" and dated March 12, 2015.

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

The Volpe Center has gathered behavioral data for travelers in the area of the U.S.-75 ICM project through surveys. The ICM Evaluation team will be collecting and analyzing field data for the post-deployment period, and the AMS team will be modeling different operating scenarios (with and without ICM) using post-deployment data as well. Collaboration between efforts will be needed to ensure that any major events that occur on the corridor are properly captured/analyzed by all three. Furthermore, traveler information parameters and assumptions were collected by both the Volpe Center travel surveys and by the ICM evaluation effort.

Volpe survey measures needed for the AMS analysis include:

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

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

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

Other Model Enhancements

Additional model enhancements will be conducted as follows:

- The network will be modified to better represent the travelshed area of the corridor, including the strategic diversion routes.
- The demand will be extended to cover the entire day. In stage 2 AMS, the model was calibrated for the AM peak period only.
- The origin-destination demand matrix will be adjusted using a select-link analysis to better match the 2014 U.S.-75 and arterial volumes.
- As part of the model reasonableness assessment effort the Dallas AMS team will modify: 1) the travel demands at different model zones; and 2) any model network geometries that may have impacts on the results of the Reasonableness Assessment.
- The model logic will be modified to be able to represent multiple signal plans that vary from a period to another.
- The model logic will be modified to represent the deployment and termination of a response plan during real-time operations as recommend by the Decision Support System (DSS).
- The logic for representing the traffic diversion during incidents will be extended to represent diversion in response to pretrip and en-route information and diversion based on the drivers' perception of the congestion ahead.
- The way measures of performance are generated will be modified to represent a moving window format (i.e., at any time instances, the network performance for a past time window of 30 minutes is produced) which is more suitable for real-time operations.
- **Ensure U.S.-75 ICM System is Accurately Represented in the Model**—To more precisely model the operation of the ICM system and evaluate its benefits, the AMS team will use ICM operational data to model the timeline from incident detection to ICM response implementation. This will allow the DIRECT model to estimate impacts of the implemented DSS logic, including latest “triggers” and “thresholds” used in the actual operation of the system. The AMS team will conduct a detailed review of model assumptions and code elements to make sure the model accurately represents the implemented ICM system.

- **DIRECT Model Better Represents Signal Timings and Phasings**—The DIRECT model will be modified to improve the way multiphase signal timings are represented in the model so that they closely represent actual field signal operations. These model improvements already are underway by Southern Methodist University (SMU) and Texas A&M Transportation Institute (TTI).
- **DIRECT Model Better Represents Vehicle Diversion**—Model parameters and structure will be refined by modifying traveler information availability to better represent route diversion and mode shift based on Volpe Center surveys.
- **DIRECT Model Represents the Full Peak Periods**—Currently, the DIRECT model uses a daily travel demand trip table with a time step of one hour. The model will be enhanced to represent continuous peak periods for both AM and PM in both directions.
- **Post-Processors**—Currently, the DIRECT model does not have the ability to calculate impacts on the reliability of travel time, emissions and fuel consumption. The AMS team will provide post-processors so it can produce inputs to the Evaluation Contractor’s travel time reliability impacts, as well as emissions and fuel consumption impacts.

Post-Deployment Alternatives Analysis

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

The potential ICM deployment-related alternatives are identified through feedback and input of the site coordinators and local agencies. The alternatives analysis will serve to assess the performance of various components of the ICM system under different scenarios and events. The methodologies, tools, and strategies incorporated into the Post-Deployment Alternatives Analysis are documented in this section, including information regarding the alternative scenarios identified for analysis and the methodologies and the modeling efforts associated with each alternative scenario.

The AMS team will focus on identifying and then representing the “as deployed” system. This includes linking the assumptions in chapter 4 about how the “with” and “without” cases are differentiated and modeled with the cluster analysis.

This AMS work will provide support to the Dallas ICM Demonstration site modeling team following the U.S. DOT-approved Post-Deployment AMS Plan. Model runs conducted in this task will be performed primarily by staff from the Dallas ICM Demonstration Site in conjunction with the AMS team.

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

Cluster Analysis

A coordinated cluster analysis was conducted by the AMS and Evaluation teams that characterizes different operational conditions in the U.S.-75 corridor, as well as the frequency of occurrence of these conditions. Based on expected impact magnitude, proposed clusters of operational conditions were identified using the following variables:

- The day on which an incident occurred.
- The time at which the incident occurred (a.m., Midday, p.m.).
- The direction the traffic was traveling (North or South).
- The number of lanes that were closed during the incident.
- The duration (in minutes) until the incident was cleared.
- The flow of traffic that was traveling during the given time and direction.
- The average number of inches of precipitation that fell on that day.
- The average travel time in minutes.

Table 5 presents a summary of identified clusters for the U.S.-75 corridor. Single incident delay impact is the difference of average travel time and the free-flow travel time of 21.24 minutes in the corridor. Total cluster delay impact for each cluster is calculated as the product of the single incident delay impact and number of days in the cluster. The right-most column shows the percent of days in a year that are represented in each cluster for each direction of travel and directional AM or PM peak period. For the southbound morning and northbound afternoon peak direction periods, no incidents occur about 30 percent of the time; the percentages given in this column are by direction period. For example cluster NB PM 3 represents an occurrence of 31.4 percent for the PM peak period and in the Northbound direction only.

Table 5. Summary of all clusters for all time periods and both directions, ordered by largest impact.

Cluster by Direction and Time Period	Number of Lanes Closed	Duration (Minutes)	Precipitation (Inches)	Travel Time (Minutes)	Single Incident Delay Impact (Minutes)	Incidents Per Period	Days In Cluster	Total Cluster Delay Impact (Minutes)	Percent of Time Period
NB PM 3	1.36	22.06	0.07	28.15	6.91	2.55	33	228.03	31.4%
SB PM 1	1.32	21.01	0.05	24.24	3.00	2.57	42	126.00	28.8%
NB PM 2	1.37	23.79	0.03	27.08	5.84	2.24	21	122.64	20.0%
SB AM 2	1.21	17.71	0.03	25.16	3.92	2.63	30	117.60	32.3%
SB AM 1	1.18	22.12	0.06	26.46	5.22	2.91	22	114.84	23.7%
SB PM 4	1.77	41.08	0.01	29.12	7.88	2.92	13	102.44	–
NB PM 4	1.43	24.25	0.05	27.63	6.39	3.14	14	89.46	13.3%

Table 5. Summary of all clusters for all time periods and both directions, ordered by largest impact (continuation).

Cluster by Direction and Time Period	Number of Lanes Closed	Duration (Minutes)	Precipitation (Inches)	Travel Time (Minutes)	Single Incident Delay Impact (Minutes)	Incidents Per Period	Days In Cluster	Total Cluster Delay Impact (Minutes)	Percent of Time Period
SB PM 2	1.39	24.89	0.03	26.24	5.00	2.54	13	65.00	–
NB PM 1	1.25	24.25	0.04	27.44	6.20	2.60	10	62.00	9.5%
SB MID 1	1.23	20.97	0.04	22.73	1.49	2.17	35	52.15	–
NB MID 3	1.17	19.34	0.03	22.78	1.54	2.13	30	46.20	–
NB AM 3	1.23	22.47	0.07	23.31	2.07	3.00	16	33.12	11.3%
NB AM 1	1.08	14.19	0.02	23.38	2.14	2.80	15	32.10	–
NB AM 4	1.12	17.51	0.06	23.33	2.09	2.53	15	31.35	–
NB AM 5	1.00	13.73	0.01	23.32	2.08	2.33	15	31.20	–
SB MID 3	1.27	20.21	0.06	23.31	2.07	2.50	14	28.98	–
SB PM 3	1.28	19.23	0.07	23.93	2.69	1.80	10	26.90	–
NB MID 4	1.12	16.32	0.04	22.96	1.72	2.50	14	24.08	–
SB MID 2	1.39	23.48	0.04	22.70	1.46	2.88	16	23.36	–
NB PM 6	1.52	41.12	0.00	27.02	5.78	3.25	4	23.12	3.8%
NB MID 2	1.48	32.80	0.04	22.99	1.75	2.62	13	22.75	–
SB AM 5	1.16	26.19	0.32	26.61	5.37	3.25	4	21.48	4.3%
SB AM 3	1.28	50.36	0.03	24.78	3.54	2.50	6	21.24	6.5%
NB MID 1	1.00	16.14	0.03	22.66	1.42	1.70	10	14.20	–
SB MID 4	1.17	24.21	0.00	22.88	1.64	2.13	8	13.12	–
SB AM 4	1.00	39.00	0.00	34.14	12.90	1.00	1	12.90	1.1%
SB AM 6	1.20	14.60	0.00	33.52	12.28	5.00	1	12.28	1.1%
NB PM 5	1.80	132.70	0.06	26.51	5.27	3.00	2	10.54	1.9%
SB MID 5	1.73	44.07	0.04	24.48	3.24	2.33	3	9.72	–
NB AM 2	1.46	57.67	0.00	23.61	2.37	2.00	4	9.48	–
NB MID 6	1.50	25.62	0.35	23.24	2.00	1.25	4	8.00	–
NB AM 6	1.36	27.89	1.04	24.91	3.67	4.50	2	7.34	–
NB MID 5	2.00	23.20	0.00	25.02	3.78	5.00	1	3.78	–
SB MID 6	1.25	42.12	0.00	22.38	1.14	3.50	2	2.28	–
SB AM 7	1.00	9.00	0.11	22.17	0.93	2.00	1	0.93	1.1%

(Source: ICM Evaluation—Dallas Cluster Analysis – Revised, Battelle, 5/19/15, p. 7, unpublished.)

The most impactful clusters of operational conditions will be analyzed using the AMS tools, and then compared to the “do nothing” alternatives representing the transportation system without ICM turned on (but with pre-ICM corridor management practices in place). These comparisons will facilitate the evaluation of impacts of the ICM system on the U.S.-75 corridor. The identification of specific incidents or other events representing individual clusters will be closely coordinated between the AMS, Evaluation and Volpe Center survey teams so as to ensure that event start and end times, impacts (such as number of lanes closed), and other characteristics are in complete agreement between the AMS, Evaluation and Survey team efforts.

For each one of the most impactful and frequent clusters a representative day with an incident and an ICM response plan was selected for AMS shown in table 6. Types of DSS response plans include Targeted Event Accelerated Response System (TEARS) traffic signal timing plan changes for the Frontage Road and Greenville Avenue, as well as without DMS messaging, with pre-ICM DMS messaging, and with a diversion message developed for ICM (e.g., “Try Greenville Avenue”), as well as incidents with an information only DSS response. All incidents with a DSS response were examined.

Table 6. Summary of representative days/incidents in the most frequent/impactful clusters during the AM and PM peak periods.

Cluster by Direction and Time Period	Post-Deployment Period			Other Information from Baseline Cluster Analysis		
	Date of Representative Day	DSS Plan Type (TEARS, DMS Message, Intended Diversion)	DSS Plan ID	Days in Cluster	Total Cluster Day Impact (minutes)	Percent of Total Time Period
NB PM 1	9/3/14	No TEARS, Information Only	J75N262 PM	10	62.00	9.5%
NB PM 2	8/8/14	TEARS, DMS 1, frontage	J75N260 PM	21	122.64	20.0%
NB PM 3*	4/21/14	TEARS, DMS 1, frontage	J75N260 PM	33	228.03	31.4%
NB PM 4	5/14/14	TEARS, DMS 2, arterial	J75N261 PM			
NB AM 3	5/5/14	No TEARS, Information Only	J75N252 PM	14	89.46	13.3%
SB AM 1	9/10/14	No TEARS, Information Only	J75N162 AM	16	33.12	11.3%
SB AM 2	9/10/14	TEARS, DMS 1, frontage	J75S260 AM	22	114.84	23.7%
SB AM 2	7/2/14	TEARS, no DMS, frontage	J75S354 AM	30	117.60	32.3%
SB PM 1	5/23/14	TEARS, DMS 1, frontage	J75S254 PM	42	126.00	28.8%
NB 6-8 PM Hypothetical	6/17/14	TEARS, DMS 1, frontage	J75S260 PM	–	–	–
Severe* Transit Hypothetical	5/2/14	Model: TEARS, DMS 3, transit; Actual: No TEARS, Information Only	J75S250 AM, J75S352 AM, J75S352 MD, N75S301 MD	n/a	n/a	n/a

(Source: ICM Evaluation—Dallas Incident Matching—Revised, Battelle, 11/13/15, p. 3, unpublished.)

* More than one DSS plans implemented for the same event.

Incident matches with response plans issued by the DSS were identified for eight clusters with a fairly high frequency of occurrence as shown in table 6. These incident matches represent a variety of DSS response plans and clusters. Two additional hypothetical scenarios were identified for AMS including:

- A ninth scenario to examine the potential benefit of extending the operation of the response system up to 8 p.m.; right now the system operates from 6 a.m. to 6 p.m. An incident that

warrants a response was selected that occurred between 6 p.m. and 8 p.m. and its duration and number of lanes closed was similar to the average incident that warranted a response in the 6 a.m. to 6 p.m. period. In AMS, a response plan will be modeled that is consistent with the DSS rules for response plan development for the Dallas ICM system. The outcome of the AMS for this scenario will be used by the Evaluation Team in a modified benefit-cost analysis that will examine the potential benefit resulting from extending the system operation period.

- A tenth scenario will be modeled to represent the potential for transit mode shift during a severe incident. Such an incident occurred on May 2, 2014; the incident lasted from 6:33 a.m. to 4:36 p.m. During that time, the Integrated Corridor Management System (ICMS) was not fully operational because of coding issues. This AMS scenario will examine the potential for mode shift during a major incident.

Analysis Approach

The U.S.-75 ICM system is activated during incidents in the corridor. Incidents are the most frequent causes of nonrecurrent congestion in the corridor, and their frequency of occurrence and impact was documented using ICM archived data; based on these data, incidents were matched with representative days for each of the 10 clusters described in the previous chapter. Each representative day will be modeled with the ICM response plan activated during the incident, and without the ICM response plan. Also, each representative day will include in addition to the primary incident any other incidents that may have occurred during that day; if the nonprimary incidents are reported as having “zero lanes blocked,” the capacity at the adjacent freeway lane will be reduced by a percentage consistent with a “blocked shoulder” in the Highway Capacity Manual. The difference between the “with ICM” and “without ICM” model runs will represent the impact of ICM for the operational condition represented by the particular cluster. The sum of all impacts across the top eight clusters shown in table 6 will represent the majority of impacts associated with the implementation of ICM in the U.S.-75 corridor.

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

Based on the Volpe Center traveler surveys, table 7 presents parameters that will be used in the AMS related to the travelers’ awareness, use and compliance to traveler information:

- “Awareness” represents the portion of travelers who have access to information.
- “Use” represents a traveler’s intent to take action, but does not necessarily result in an action, unless the proposed mode-route option is more attractive than the “historical route,” based on the model’s diversion rules. Therefore, “use” reflects an upper bound on the percent of travelers who might divert as a response to the information, with the actual percentage dependent on the attractiveness of the new route and referred to as “Compliance.” For better linearity of model functions (nonjumpiness across steps) the model uses this convention, where “compliance”=“awareness” * “use.”

- This AMS effort (as reported in table 7) will use the compliance numbers reported in the pulse summary tables provided by the Volpe Center on June 22, 2015. These are the combined compliance numbers across AM and PM pretrip and en route, unweighted. These traveler responses excluded responses recorded after a major pedestrian fatality incident, because the overall team considered this event as an outlier.
- For awareness the AMS will use the percentages from the Volpe Center’s baseline/endline surveys, and they are both in the mid 90 percent range.

Table 7. Dallas U.S.-75 corridor—traveler information parameters used in analysis, modeling, and simulation (Percent).

	Pretrip			En-Route		
	Awareness	Use	Compliance	Awareness	Use	Compliance
Pre ICM						
Survey 6/23/15 compliance	94.00	17.39	16.35	92.00	28.26	26.00
Post ICM						
Survey 6/23/15 compliance	96.00	19.15	18.38	95.00	29.47	28.00

(Source: Overview of the Dallas Traveler Response Panel Survey—Draft, Volpe Center, 5/18/16.)

Table 8 shows the analysis settings for conducting Post-Deployment AMS for the Dallas U.S.-75 corridor.

The AMS effort will produce performance measures for travel time, delay, throughput, vehicle- and person-hours of travel, vehicle- and person-miles of travel, and travel time reliability for the entire U.S.-75 corridor area or segment within the corridor by peak period, by facility type (e.g., mainline, frontage road, and local street), by mode, and by direction of travel. The U.S.-75 Corridor AMS will also produce model outputs for use by the Evaluation Contractor to estimate emissions and fuel consumption, associated with the deployment of ICM strategies. The data provided to the Evaluation Contractor will include: a) link lengths, link characterization (freeway, major arterial, frontage road, minor arterial) and average grade for all network links; and b) average hourly directional link volumes and speeds for the U.S.-75 freeway, the frontage roads, Greenville Avenue and other strategic and relevant north-south arterials, and arterial links connecting the U.S.-75 freeway to potential diversion routes. The emissions analysis methodology will incorporate reference values to identify the emissions and fuel consumption rates based on variables, such as facility type, vehicle mix, and travel speed. The emissions and fuel consumption rates will be based on available sources. Emissions will be computed by pollutant, mode, and facility type. Fuel consumption will be computed by fuel type, mode, and facility type.

Table 8. Dallas U.S.-75 corridor—summary of post-deployment analysis settings.

Parameter	Value	Comment
Analysis year	2014	The analysis year was derived from the anticipated completion of design, testing, and deployment of ICM.
Time period of analysis	AM peak period (6 a.m. to 10 a.m.) PM peak period (3 p.m. to 7 p.m.)	Several incidents that occurred in days representative of different clusters, and for which response plans were activated were selected to represent in both AM and PM peak periods. Also, two hypothetical scenarios were selected for analysis, including: 1) an incident that occurred between 6 and 8 p.m.; and 2) a severe incident that would have triggered a transit mode shift response.
Simulation period	4 hours in each peak period	6-10 a.m. and 3-7 p.m. were selected to represent the AM and PM analysis periods.
Freeway incident locations and durations	Based on cluster analysis and presented in table 6	These locations experienced incidents, offered the potential for route diversion, had a response plan activated, and had a high impact on corridor travel.

(Source: Cambridge Systematics, Inc.)

For the identified ICM strategies and based on input by the Evaluation Contractor, planning-level cost estimates will be prepared for lifecycle costs (capital, operating, and maintenance costs).

Within each of the capital, operations and management (O&M), and annualized cost estimates, the costs are further disaggregated to show the infrastructure and incremental costs. The costs will be estimated for each scenario and a benefit-cost ratio will be assigned to all the individual performance measures. The annualized benefits for each of the measures mentioned above will be calculated using cluster frequencies of occurrence as presented in table 6.

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

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

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

- Description of the context of AMS within the ICM program to orient an unfamiliar audience.
- Explanation of the key roles of AMS in the ICM Program, including a description of the following:
 - Developing methodologies that support the process for continuous improvement.
 - Identifying when and where ICM strategies will be the most beneficial.
 - Supporting the ICM evaluation.

- Developing the analytical capital within each site so that the analyses can be conducted on a regular basis to support ICM decisionmaking (either in planning mode or DSS mode).
- Explanation of the AMS process (i.e., “what was done,” the “how it was done”).
- Articulation of results in terms of benefits, particularly on days with high demand and a major incident.
- Explanation of caveats for credibility regarding the calibration, validation and methodology.
- Specific lessons learned in the AMS, including specific examples such as:
 - A well documented Analysis Plan provided value with the sites to refine the details of their strategies and how they are expected to be deployed.
 - The operational conditions analysis combined with the strategy refinement were critical outcomes of the AMS effort even if the models had never been run.

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

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

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

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

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

Chapter 8. Schedule and Allocation of Responsibilities

This section provides a summary of work plan tasks and subtasks, deliverables, lead responsibility, and schedule associated with Post-Deployment Analysis, Modeling, and Simulation (AMS), as shown in table 9. The Post-Deployment AMS efforts will be a collaborative effort between Cambridge Systematics (Integrated Corridor Management (ICM) AMS Contractor), Dallas Area Rapid Transit (DART) including DART's team, and Battelle (ICM Evaluation Contractor). Table 9 describes the division of responsibilities and each agency's role for each of the AMS tasks. Table 10 presents key coordination points between the ICM AMS, Evaluation, Sites, and Volpe Center efforts.

Table 9. Post-Deployment Analysis, Modeling, and Simulation—schedule and allocation of responsibilities.

No.	Task and Work Plan Items	Deliverables	Responsibility (Lead in Boldface)	Completion Date
1	Project Management and Program Support			
	1. Kickoff meeting in Dallas	Meeting minutes	U.S. DOT, CS , Volpe Center Battelle, TTI, DART, SMU	October 23, 2013
5.7	Dallas Post-Deployment AMS Plan			
	1. Development of Draft Analysis Plan	Analysis Plan Draft	CS	September 26, 2014
	2. Review of Analysis Plan	Comments due	TTI, U.S. DOT , Volpe Center, Battelle	October 3, 2014, TTI October 17, 2014, U.S. DOT May 2015, U.S. DOT August 2015, U.S. DOT October 2015, U.S. DOT
	3. Respond to comments	Revised Analysis Plan	CS	November 7, 2014 and one-month increments after subsequent reviews
	4. Final Analysis Plans/Approvals	Final Analysis Plan	CS , U.S. DOT	August 4, 2015 December 2015
	5. Site visits		CS , U.S. DOT	November 7/8, 2013 June 10, 2015

U.S. DOT = U.S. Department of Transportation; CS = Cambridge Systematics, Inc.; TTI = Texas A&M Transportation Institute; DART = Dallas Area Rapid Transit; SMU = Southern Methodist University

Table 9. Post-Deployment Analysis, Modeling, and Simulation—schedule and allocation of responsibilities (continuation).

No.	Task and Work Plan Items	Deliverables	Responsibility (Lead in Boldface)	Completion Date
5.8	Enhance Tools to Reflect Post-Deployment Conditions			
	1. Select analysis tool		CS , TTI, SMU	December 31, 2013
	2. AMS tool reasonableness assessment	Draft Technical Memorandum	CS, SMU , TTI	December 31, 2014
	3. Collaboration with Volpe Center survey and ICM evaluation		CS, Volpe Center, Battelle	Ongoing
	4. Model Enhancements	Draft Technical Memorandum	CS, SMU , TTI	December 31, 2014
	5. Review of Technical Memoranda	Comments due	U.S. DOT , DART	January 15, 2015 U.S. DOT Acceptance on April 28, 2015
	6. Respond to comments and produce final versions of Technical Memoranda	Revised memoranda	CS	May 10, 2015
	7. Implement modifications in model	Final baseline models	SMU , TTI, DART, CS	May 10, 2015
5.9	Post-Deployment Alternatives Analysis			
	1. Establish alternatives analysis scenarios	Part of Analysis Plan	CS , TTI, DART, Volpe Center, Battelle	August 15, 2015
	2. Post-deployment model runs and post-processor results	Post processor results and documentation of impacts	SMU, TTI , CS	February 28, 2016
	3. Submit draft Dallas ICM Post-Deployment Interim Results Briefing for comments	Draft briefing	CS , DART, TTI	March 15, 2016
	4. Review of draft Interim Results Briefing	Comments due	U.S. DOT , DART, Volpe Center, Battelle	April 15, 2016
	5. Respond to comments and prepare final Interim Results Briefing	Final Assessment Briefing	CS	May 15, 2016

U.S. DOT = U.S. Department of Transportation; CS = Cambridge Systematics Inc.; TTI = Texas A&M Transportation Institute; DART = Dallas Area Rapid Transit; SMU = Southern Methodist University

Table 9. Post-Deployment Analysis, Modeling, and Simulation—schedule and allocation of responsibilities (continuation).

No.	Task and Work Plan Items	Deliverables	Responsibility (Lead in Boldface)	Completion Date
5.10	ICM Post-Deployment Assessment Report and Related Materials			
	1. Submit draft ICM Demonstration Site Post-Deployment Assessment Report for comments	Draft Post-Deployment Assessment Reports	CS	February 28, 2016
	2. Review of draft Assessment Report	Comments due	U.S. DOT, DART, Volpe Center, Battelle	March 15, 2016
	3. Respond to comments and prepare Final Assessment Report	Final Assessment Reports	CS	March 30, 2016
	4. Submit draft ICM Demonstration Site Post-Deployment Assessment Briefing for comments	Draft Post-Deployment Assessment Briefing	CS	March 15, 2016
	5. Review of draft Assessment Briefing	Comments due	U.S. DOT, DART, Volpe Center, Battelle	March 30, 2016
	6. Respond to comments and prepare final Assessment Briefing	Final Assessment Briefing	CS	April 15, 2016
	7. Presentation of Post-Deployment Assessment Briefing	Presentation	CS	April 15, 2016
	8. Results of the modeling analysis for incorporation into the overall evaluation report	Evaluation Report Technical Memorandum	CS, TTI, DART	March 15, 2016
	9. Electronic files, data and tools used for conducting the post-deployment AMS of U.S.-75 ICM	Files, data and tools	CS, TTI, DART	April 15, 2016
	13. Submit draft ICM Demonstration Site Post-Deployment Summary Briefing	Draft Post-Deployment Summary Briefing	CS	May 1, 2016
	14. Review of draft Summary Briefing	Comments due	U.S. DOT, TTI, Battelle	May 15, 2016
	15. Respond to comments and prepare final Summary Briefing	Final Summary Briefings	CS	May 30 2016

(Source: Cambridge Systematics, Inc.)

U.S. DOT = U.S. Department of Transportation; CS = Cambridge Systematics, Inc.; TTI = Texas A&M Transportation Institute; DART = Dallas Area Rapid Transit; SMU = Southern Methodist University

Table 10. Example key points of integrated Corridor Management Coordination related to Analysis, Modeling, and Simulation.

General Topic	Subtopic	Text Descriptions/“Process Input”	Evaluation Plan/ Observed Data (<i>Evaluation team (Battelle)</i>)	Modeling Plan (<i>AMS team (Cambridge Systematics, Inc.)</i>)
No-ICM Alternative System Management “How we used to do it”	Traffic Signal Control Capabilities	<p>(Sites)</p> <ul style="list-style-type: none"> • base plans and settings by time of day • adaptation triggers and alternative plans • adaptation: where possible, when, time to implement 	FOR EACH ITEM, how well differentiated in time-series data, quantify some of aspects of system management (e.g., measured time-to-implement.)	FOR EACH ITEM, how well can the selected model(s) represent this aspect of systems management, and what enhancements (if any) can be considered to improve this representation.
	Traveler Information Capabilities	<p>(Sites)</p> <ul style="list-style-type: none"> • base messaging and continuous features • triggers and alternative messages (if any) • info scope, precision and update cycle • pretrip versus en-route considerations 		
	Incident Management	<p>(Sites)</p> <ul style="list-style-type: none"> • response triggers and response descriptions • adaptation: where possible, when, time to implement 		
With-ICM Alternative System Management “How we do it now or will do it”	Traffic Signal Control Capabilities	<p>(Sites)</p> <ul style="list-style-type: none"> • base plans and settings by time of day • adaptation triggers and alternative plans • adaptation: where possible, when, time to implement 	FOR EACH ITEM, how well differentiated in time-series data, quantify some of aspects of system management (e.g., measured time-to-implement).	FOR EACH ITEM, how well can the selected model(s) represent this aspect of systems management, and what enhancements (if any) can be considered to improve this representation.
	Traveler Information Capabilities	<p>(Sites)</p> <ul style="list-style-type: none"> • base messaging and continuous features • triggers and alternative messages (if any) • info scope, precision and update cycle • pretrip versus en-route considerations 		

Table 10. Example key points of integrated Corridor Management Coordination related to Analysis, Modeling, and Simulation (continuation).

General Topic	Subtopic	Text Descriptions/“Process Input”	Evaluation Plan/ Observed Data	Modeling Plan
	Incident Management	<p>(Sites)</p> <ul style="list-style-type: none"> • response triggers and response descriptions • adaptation: where possible, when, time to implement 		
Operational Conditions and Playbook		<ul style="list-style-type: none"> • under condition X, we adapt in the following ways, until some future time, when there is a return to base control settings 	Determine the set of [X] operational conditions, including frequency of occurrence. Where are there comparable with/without cases in the observed data? What other cases are needed from modeling?	Identifies the set of modeling runs to be conducted, specific conditions [X1, X2, X3...] and the two alternative actions in each case (no-ICM and with-ICM).
Traveler Behavior	Survey	<p>(Volpe)</p> <ul style="list-style-type: none"> • information utilization rates • decisionmaking (possibly different with/without) • disaggregate models of traveler behavior 	Observed diversion rates and conditions on days where behavior is modeled.	Describe how well represented and what enhancements (if any) can be considered to improve behavioral modeling, plan validation of incident cases using observed data.
Performance Measurement	Measures	<ul style="list-style-type: none"> • National Guidance 	Define key measures derived from observed data.	Define key measures derived from simulation data, as consistent as possible with those from observed data.
	Assumptions		Set out-year assumptions on demand changes, timeframe of C/B analysis, value of time.	Utilize consistent out-year assumptions on demand changes, timeframe of benefit-cost analysis, value of time.

(Source: Karl Wunderlich, Noblis.)

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- Harder, Kathleen A., et al. "Route preferences and the value of travel-time information for motorists driving real-world routes." (2005).
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Appendix A. List of Acronyms

AMS	Analysis, Modeling, and Simulation
BRT	Bus Rapid Transit
DART	Dallas Area Rapid Transit
DIRECT	Dynamic Intermodal Routing Environment for Control and Telematics
DMS	Dynamic Message Sign
DOT	Department of Transportation
DSS	Decision Support System
GPS	Global Positioning System
HOV	High-Occupancy Vehicle
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
ITS	Intelligent Transportation Systems
LRT	Light Rail Transit
MPO	Metropolitan Planning Organization
NCTCOG	North Central Texas Council of Governments
NTTA	North Texas Tollway Authority
OD	Origin-Destination
O&M	Operations and Maintenance
PGBT	President George Bush Turnpike
PHT	Person Hours Traveled
PMT	Person Miles Traveled
SH	State Highway
SMU	Southern Methodist University
SOV	Single-Occupant Vehicle
TEARS	Targeted Event Accelerated Response System
TMC	Traffic Management Center
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
VHT	Vehicle Hours Traveled
VMT	Vehicle Miles Traveled
VPH	Vehicles Per Hour

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ITS Joint Program Office-HOIT
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