Traffic Analysis Toolbox Volume XIII:

Integrated Corridor Management Analysis, Modeling, and Simulation Guide

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16. Abstract

As part of the Federal Highway Administration (FHWA) Traffic Analysis Toolbox (Volume XIII), this guide was designed to help corridor stakeholders implement the ICM AMS methodology successfully and effectively. It provides a step-by-step approach to implementation of the ICM AMS methodology and reflects lessons learned in its application to the three ICM Pioneer Sites and a test corridor. It is specifically targeted at technical and/or program managers in transportation agencies at the State or local level who may oversee implementation of ICM and/or an ICM AMS initiative. This Guide will also be a helpful reference to all stakeholders involved in AMS, including technical modelers, by providing a framework for developing an effective analysis plan to support selection and application of available tools and models specifically conducive to ICM.

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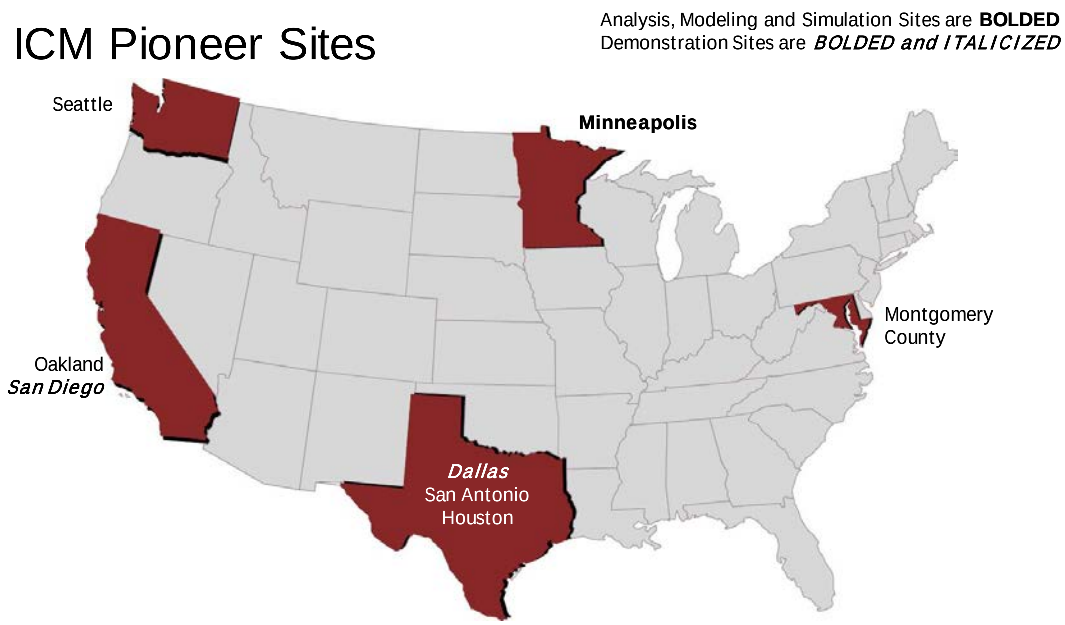
Chapter 1 Introduction and Background

1.1 Overview of Integrated Corridor Management (ICM)

Integrated Corridor Management (ICM) involves the coordination of transportation management techniques among networks in a corridor that together can collectively address congestion and improve overall corridor performance. The objective of the United States Department of Transportation (USDOT) 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 these strategies – to help manage congestion in our nation's busiest corridors.

As part of this initiative, the USDOT partnered with eight "Pioneer Sites," selected to explore the institutional guidance, operational capabilities, ITS technology, and technical methods needed for effective ICM. In 2008, three of the Pioneer Sites (Dallas, TX; Minneapolis, MN; and San Diego, CA) were selected to conduct Analysis Modeling and Simulation (AMS) of their ICM concepts. Two sites (Dallas, TX and San Diego, CA) have been selected to demonstrate their ICM systems. These demonstrations are expected to occur in 2013-2014 timeframe. Figure 1-1 depicts the ICM Pioneer Sites.

Figure 1-1. ICM Pioneer Sites



[Source: Research and Innovative Technologies Administration, ITS JPO.]

There are many corridors in the country with underutilized capacity (in the form of arterials, freeway travel lanes and parallel transit capacity; e.g., bus, rail, bus rapid transit [BRT], etc.) that could benefit from ICM. The maturation of ITS technologies, availability of supporting data, and emerging multiagency institutional frameworks make ICM practical and feasible. There are a large number of freeway, arterial, and transit optimization strategies available today and in widespread use across the United States. Most of these strategies are managed locally by individual agencies on an asset-by-asset basis. Even those managed regionally are often managed in a stove-piped manner (asset-by-asset) rather than in an integrated fashion across a transportation corridor. Dynamically applying these strategies in combination across a corridor in response to varying conditions is expected to reduce congestion "hot spots" in the system and to improve the overall productivity of the system. Furthermore, providing travelers with actionable information on alternatives (such as mode shift, time of travel shift, and route shift) is expected to mitigate bottlenecks, reduce congestion, improve the resilience of the system during major incidents, and empower travelers to make more informed travel choices. ICM facilitates, is complementary to, and is enhanced by related multidisciplinary, multijurisdictional, performance-driven initiatives, including active transportation and demand management (ATDM), traffic incident management (TIM) programs, Regional Concepts for Transportation Operations (RCTO), and objectives-driven, performance-based planning for operations efforts.[1]

> *"Typical corridor studies have a fairly narrow perspective: they don't start with the tripmaking from the point of true origin, or factor in the broad range of traveler choices that affects who shows up, when and where, in the corridor. Stakeholders may say 'We do corridor studies all the time, why do we need AMS?' ICM AMS is a different kind of corridor study, a comprehensive study."*
>
> Karl Wunderlich, Senior ICM AMS Technical Advisor, Noblis

> ICM aims to optimize existing transportation infrastructure to help manage congestion in our nation's busiest corridors.

1.2 Introduction to ICM AMS

The ICM initiative developed an AMS methodology to assist corridor managers in forecasting and assessing the potential benefits and implications of ICM in their corridors of interest. The ICM AMS Guide has been incorporated into the Federal Highway Administration (FHWA) Traffic Analysis Toolbox (Volume XIII) and Traffic Simulation Guidelines.[2] Unlike traditional corridor studies, which often focus on a specific element of a corridor (i.e., a freeway or freeway and frontage road during a specific time of day), ICM AMS is a comprehensive approach that analyzes different operational conditions across time and modes and across a large enough geographic area to absorb all impacts.

The complexity involved in this type of analysis goes far beyond what is typically required for more traditional types of transportation investments. The potential inclusion of multiple facility types (freeway and arterial) and multiple transportation modes, combined with the potential for road use pricing influences, complicates the analysis. The focus of the ICM strategies on non-typical operations scenarios (e.g., high demand, incidents, inclement weather) adds further complexity to the assessment. Finally, the ICM AMS methodology enables a more sensitive analysis of corridor-level performance. Traditional travel demand models are sufficient for analyzing the impacts of major infrastructure investments, such as new freeways. But when agencies are interested in fine-tuning transportation operations strategies to produce system-wide improvements that optimize existing infrastructure performance, they need time-dynamic tools that are more sensitive and that enable insight into the benefits that are otherwise too marginal to see in traditional modeling. The ICM AMS

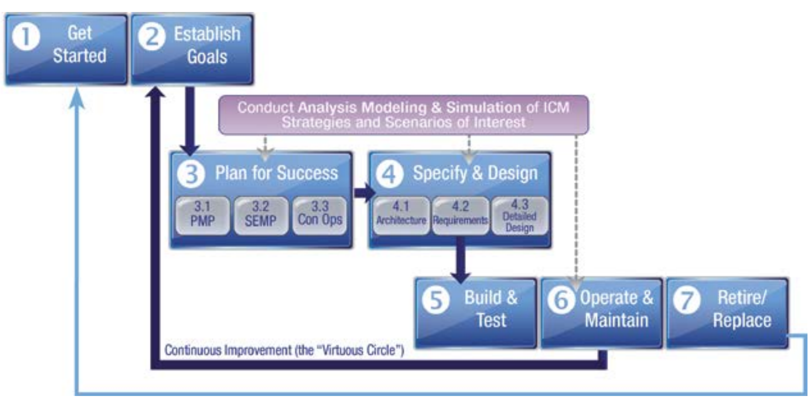
[1] For more information, visit these program web pages, available at FHWA's Office of Operations web site: http://ops.fhwa.dot.gov/.
[2] Please visit the FHWA Traffic Analysis Toolbox web page for more information (http://www.ops.fhwa.dot.gov/trafficanalysistools/index.htm).

approach is neither inexpensive nor easy to accomplish. However, the value gained outweighs the expense and pays dividends throughout an ICM Initiative by reducing the chance of very expensive missteps in implementation; streamlining the implementation process; and allowing corridor stakeholders to deploy ICM AMS more rapidly and at a lower cost, given the lessons learned in this effort.

One of the defining features of the ICM AMS methodology is that it enables agencies to understand system dynamics at the corridor level. The ICM AMS methodology uses corridor-level performance metrics rather than facility-level metrics to evaluate and understand corridor performance. The ICM AMS methodology accomplishes this through the combined use of multiple classes of available modeling tools. By combining aspects of macrosimulation (i.e., travel demand modeling (TDM), good for analyzing implications associated with mode shift), mesosimulation (utilized to analyze regional strategies such as traveler information and pricing), and microsimulation (ideal for analyzing traffic control strategies), the ICM AMS methodology enables robust hypothesis modeling under a range of operating conditions of interest to the corridor for more informed decisionmaking. This produces improved analysis as compared to travel demand models alone because the combined tools yield more accurate travel times and speeds through the corridor, more in-depth understanding of bottleneck locations and their root causes, and an understanding of the influences beyond the periphery of the corridor that underlie corridor demand. The use of the different models allows specific strengths of the individual models to be combined: travel demand models provide estimates of long-term travel demand changes resulting from capacity changes or pricing strategies, while more focused meso- and microsimulation models assess short-term operational impacts during specific non-recurring congestion conditions.

The AMS approach is intended to be a flexible and iterative process adaptable to a wide variety of conditions, strategies, and situations. This flexibility is intended to provide practitioners with sufficient structure to enable a rigorous analysis suitable to complex strategies that at the same time is not so rigid as to limit the ability to restructure and rerun the analysis to address project contingencies as they occur. The AMS approach is designed to be implemented in conjunction with the ICM system development and design process,[3] and to provide a tool for continuous improvement of corridor performance as depicted in Figure 1-2. Regular periodic conduct of ICM AMS also supports continuous improvement of the supporting ICM system, and the models themselves.

Figure 1-2. ICM Implementation Process Phases



[Source: Research and Innovative Technologies Administration, ITS JPO.]

As the AMS process continues in parallel with the ICM system development and design process, it is likely that new strategies, alternatives and scenarios will emerge that will need to be evaluated within the AMS process; therefore, the flexibility to foresee and account for several iterations of analysis is critical. The design process

[3] The ICM implementation process follows the systems engineering lifecycle process.

may reveal new strategies or alternatives that may need to be analyzed in the AMS, prompting modifications to the AMS structure. Likewise, the AMS process may reveal parts of the concept of operations that are unworkable or uncover opportunities that may be leveraged that result in changes to the ultimate ICM design.

The advanced analysis capabilities of the AMS approach provides practitioners with enhanced opportunities to conduct detailed alternatives analysis to identify optimal combinations of strategies and to test and refine how the strategies may be most optimally implemented. Due to the complexity and resources required of the AMS, this level of analysis is typically most appropriate in the later planning stages after the preliminary screening of alternatives has winnowed out a smaller set of strategies and alternatives to be evaluated. The AMS will often continue through the design phase – being used to fine-tune strategies in an iterative function as the realities of the design process progress or to assess the impacts of sequencing the improvements to identify the optimal deployment phasing of the strategies.

However, these greatly expanded analysis capabilities come at a cost. The AMS approach is demanding in terms of data needs, staff skill levels, and the amount of time and resources that need to be devoted to implement and conduct the analysis successfully. Practitioners should not underestimate these requirements. Caveats to practitioners include:

- Significant data are needed to conduct the analysis. These data need to be high-quality, reliable, and provide continuous coverage over long-periods of time (minimum of 6 to 12 months) to be of use to the AMS process. If data fitting the requirements of the AMS are not readily available, the costs and resources necessary to conduct the analysis will need to be expanded significantly in order to collect and analyze the necessary data. Using poor-quality or insufficient data will produce inaccurate results that may lead to poor investment decisions.

- Staff skill levels must be suitable to the challenge. The complexity of not only using advanced travel demand models and simulation models independently, but also integrating and calibrating these multi-resolution models is challenging even to many advanced users. Agencies with only cursory or even intermediate skills in any one of the modeling platforms should plan either to add budget for staff training or to acquire consultant services to meet these needs.

- Even if data are available and staff skills are robust, the cost of compiling and analyzing the baseline data, developing the analysis framework, calibrating the tools, and completing the analysis is significant and should only be undertaken in situations where the risk of making a poor investment decision outweigh the costs.

Successfully completing the AMS process for an ICM or other strategy analysis is neither inexpensive nor trivial; however, the potential cost savings from avoiding wrongly focused deployments based on inadequate analysis, along with the maximization of potential ICM system benefits through the optimization of the strategies can result in a substantial pay-back on the investment in AMS. For the Pioneer Sites, the costs of developing and conducting the AMS accounted for approximately 5 percent of the overall deployment budget.[4] If the analysis was successful in better structuring the deployment to increase the efficiency of the ICM by a minimum of 5 percent, or reduced the risk of a deployment cost overrun of 5 percent or more, the investment in AMS paid for itself. The partners at the Pioneer Sites felt there was significant value in AMS, which greatly outweighed the analysis costs.

[4] The AMS costs for the Pioneer Sites were likely proportionately higher than they would be in future analysis, due to the need to develop and refine new analysis methods and procedures. Hopefully, the best practices from this development procedure, highlighted in this AMS Guide, can be leveraged by subsequent practitioners to reduce the costs of conducting these activities.

ICM AMS Methodology Components

The ICM AMS Methodology provides a pragmatic roadmap to guide practitioners through this complexity while not being too rigid and allowing for flexibility in addressing project contingencies. The ICM AMS methodology allows each corridor to define a specific analytic approach that includes supporting tools, model calibration methodology, analysis for different operational conditions, performance measures, analysis plans, and calculation of ICM benefits. For the ICM AMS Pioneer Sites, existing candidate AMS tools were evaluated and compared for their ability to model ICM strategies. Findings from this evaluation revealed that existing models share certain common features, but vary widely in their implementations and data requirements.

Every tool type represents a tradeoff between geographic scope and level of resolution (scale vs. complexity). Less detailed tool types are tractable for large networks, while more detailed tool types are restricted to smaller networks. Depending on corridor size and the types of analyses required, all tool types are potentially valuable for ICM AMS. Microscopic simulation models, for example, are effective at analyzing system optimization strategies, such as freeway ramp metering and arterial traffic signal coordination, while mesoscopic simulation models are less effective, and travel demand models do not have this analysis capability. Travel demand models are better at estimating mode shift, but microscopic and mesoscopic simulation models are better at estimating route shifts. Mesoscopic tools can estimate regional dynamic diversion of traffic, while microscopic tools can estimate route shift at a smaller geographic scale. Finally, mesoscopic simulation tools are better at analyzing traveler responses to congestion pricing. The ICM AMS offers corridor managers greater capability than is available in any single existing tool.

AMS Supporting Tools

Three findings emerged from the analysis of capabilities found in existing AMS tools as applied to the ICM AMS Pioneer Sites:

1. Each tool type has different advantages and limitations and is better than other tool types at some analysis capabilities. There is no one tool type at this point in time that can successfully address the analysis capabilities required by the ICM program. An integrated approach can support corridor management planning, design, and operations by combining the capabilities of existing tools.

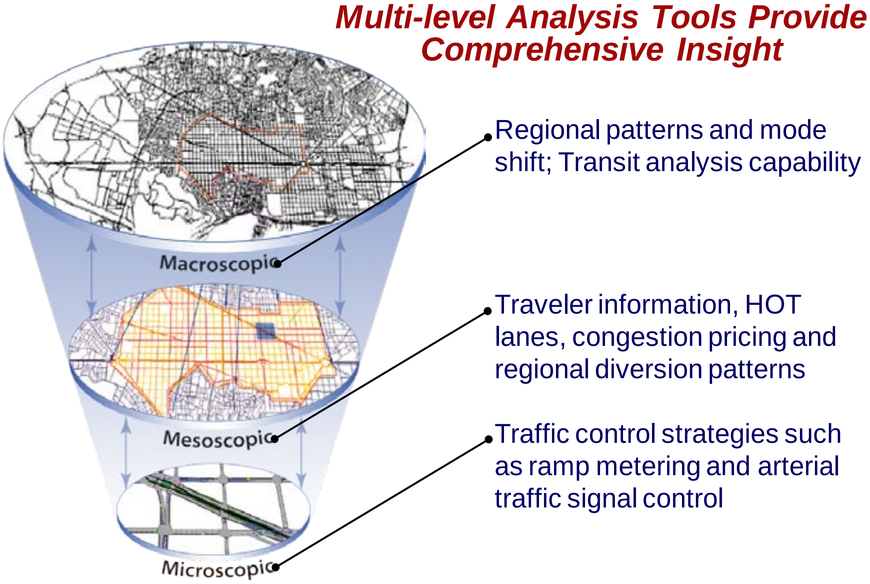
2. Key modeling gaps in existing tools' capabilities include: a) the analysis of traveler responses to traveler information; b) the analysis of strategies related to tolling/high occupancy tolling (HOT) lanes/congestion pricing; and c) the analysis of mode shift and transit in the short-term.

3. Interfacing between different analysis tool types presents challenges that were addressed by identifying interface requirements that focus on: a) maintaining consistency across analytical approaches in the different tools, and b) maintaining the consistency of performance measures used in the different tool types. Multi-resolution modeling is an emerging field – some of these challenges are being addressed by tool developers creating suites of tools that are internally consistent.

The ICM AMS methodology encompasses tools with different traffic analysis resolutions. Up to three classes of simulation modeling approaches – macroscopic, mesoscopic, and microscopic – are considered and can be integrated within the ICM AMS methodology. Figure 1-3 presents a graphical depiction of the geographic scope of, and interrelationships between, these tools. The modeling approaches developed for different corridors involved significant tailoring of the general methodological approach. Depending on the scope, complexity, and questions to be answered within each corridor, there was more or less emphasis on each of the three general model types and their interaction.

The ICM AMS methodology includes macroscopic trip table manipulation for the determination of overall trip patterns, mesoscopic analysis of the impact of driver behavior in reaction to ICM strategies (both within and between modes), and microscopic analysis of the impact of traffic control strategies at roadway junctions (such as arterial intersections or freeway interchanges). The methodology also includes a simple mode shift model and a transit travel time estimation module, interfaces between different tools, and a performance measurement/benefit-cost module.

Figure 1-3. The ICM AMS Methodology Blends Up to Three Classes of Modeling Tools for Comprehensive Corridor-Level Modeling and Analysis



[Source: Cambridge Systematics, Inc., September 2009.]

Model Calibration and Validation

Accurate calibration is a necessary step for proper simulation modeling. Before modeling ICM strategies, model calibration ensures that base scenarios represent reality (e.g., model-generated speeds are approximately those observed through ground measurement), creating confidence in the scenario comparison. Validation is the process of ensuring that model parameters and assumptions are reasonably within known boundaries or limitations of human behavior (e.g., driver's reaction time assumed in a simulation model should not exceed human capabilities). Before ICM strategies were analyzed, model validation/calibration criteria were identified for the ICM AMS modeling effort.

Because of the transit presence in two of the ICM AMS corridors, model validation and calibration criteria were established for the transit component of the analysis and modeling (See Workstep 3, "Model Setup and Calibration," for more information).

Analysis for Different Operational Conditions

The ICM AMS Methodology employs tools and procedures capable of supporting the analysis of multimodal travel scenarios under varying operational conditions, in particular both recurrent and nonrecurrent traffic congestion. A corridor's nonrecurrent congestion scenarios entail combinations of demand increases and capacity decreases. The overall premise is that key ICM impacts may be lost if only "normal" travel conditions are considered. The proposed ICM scenarios take into account both average- and high-travel demand within the corridor, with and without incidents. The relative frequency of nonrecurrent operational conditions (i.e., incidents or other significant nonrecurrent operational conditions that affect corridor performance such as work zones, special events, weather, etc.) is also important to estimate (based on archived traffic conditions) in this process.

Performance Measures

The following represent categories of performance measures used in ICM analysis. A fifth area that may be of interest to corridor managers, safety, is not included because available safety analysis methodologies are not measurably sensitive to ICM strategies.

- **Mobility** – Describes how well the corridor moves people and freight. Three primary types of measures were used to quantify mobility: travel time, delay, and throughput;
- **Reliability** – Captures the relative predictability of the public's travel time;
- **Emissions and Fuel Consumption** – Captures the impact on emissions and fuel consumption; and
- **Benefits and Cost Comparison** – Measures the effectiveness of the investment relative to its cost.

The Value of the ICM AMS Methodology

Investing in ICM and AMS is a major undertaking that requires stakeholders to agree to the value proposition. Certainly, the ICM AMS methodology can provide valuable insight into the potential cost-benefits of ICM. The specific cost-benefit analysis results will vary by corridor. However, the general value of implementing the ICM AMS methodology is the extent to which it assists corridor stakeholders implementing ICM to:

- **Invest in the right strategies** – AMS analysis offers corridor managers a predictive forecasting capability that they lack today to help them determine which combinations of ICM strategies are likely to be most effective and under which conditions:

  > *AMS helps decision-makers identify technical and implementation gaps, evaluate ICM strategies, and invest in the combination of strategies that would most minimize congestion and produce the greatest benefits. Comprehensive modeling increases the likelihood of ICM success and helps minimize the unintended consequences of applying ICM strategies to a corridor. It provides an enhanced understanding of existing corridor conditions and deficiencies, allowing for the improved ability to match and configure proposed ICM strategies to the situation at hand.*

- **Invest with confidence** – AMS allows corridor managers to "see around the corner" and discover optimum combinations of ICM strategies, as well as potential conflicts or unintended consequences inherent in certain combinations of strategies that would otherwise be unknowable before full implementation:

  > *AMS helps managers estimate the benefits resulting from ICM across different transportation modes and traffic control systems. Importantly, it helps managers to align these estimates with specific assumptions about corridor conditions and ICM strategies. Without being able to predict the effects of ICM strategies corridor transportation agencies may not take the risk of making the institutional and operational changes needed to optimize corridor operations.*

- **Lower risk associated with implementation –** AMS facilitates the detailed development of concepts of operations and requirements by stakeholders, and helps corridor managers define and communicate key analysis questions, project scope, partner roles, and partner responsibilities. AMS facilitates the development of concepts of operations and requirements by stakeholders in more detail, and helps corridor managers understand in advance what questions to ask about their system and potential combinations of strategies to make any implementation more successful:

  The development of the analysis plan may help identify flaws or technical issues in the Implementation Plan or Concept of Operations (CONOPS) that may have been otherwise overlooked. Following the ICM AMS methodology helps to communicate the scope of the project and appropriately set expectations among differing project stakeholders (e.g., planners, operators, data analysts, modelers, and agency management from State, local, and/or regional transportation agencies), and provides a clearer definition of expected roles and responsibilities. AMS also helps managers identify and prioritize resources to project objectives, allowing for the effective and efficient allocation of resources and more sound project management.

  For example, in the San Diego I-15 AMS it was discovered that the strategy of opening the managed lanes to all traffic during a major incident would impact the performance of the Bus Rapid Transit (BRT) system, resulting in lower ridership levels and overall BRT system inefficiencies. In response to this finding, the ICM design has placed emphasis on the distribution of accurate and real-time BRT transit information. This includes individual bus locations and on-off real-time ridership boardings that will be part the I-15 ICM system to help system operators manage the corridor in an efficient and integrated approach. Such information will also be distributed and available to I-15 corridor travelers to provide transportation choices during major incidents or during recurring congestion.

- Provides a long-term capability to corridor managers to **continually improve implementation** of ICM strategies based on experience. The Continuous Improvement workstep ensures the maintenance of the models and datasets, thus greatly reducing the costs and increasing the ease with which future analysis can be conducted.

  Following the methodology results in enhanced datasets, tools, and processes that may be used in improving future planning and analysis efforts. Finally, it creates a rich knowledge base of historic, predicted and actual corridor conditions that can help to advance collective knowledge through the transfer of learning within agencies and to the transportation community at large.

AMS is an integral part of ICM, providing for:

- Improved alternatives analysis;
- Improved situational awareness;
- More trusted models; and
- Continuous improvement of corridor performance.

1.3 Purpose of the Guide

The purpose of this document is to help corridor stakeholders implement the ICM AMS methodology successfully and effectively. This guide provides a step-by-step approach to implementation of the ICM AMS methodology, and reflects lessons learned in its application to the three ICM Pioneer Sites and a test corridor. It is specifically targeted at technical and/or program managers in transportation agencies at the State or local level who may oversee implementation of ICM and/or an ICM AMS initiative. It presumes familiarity with ICM. This guide will also be a helpful reference to all stakeholders involved in AMS, including technical modelers, by providing a framework for developing an effective analysis plan to support selection and application of available tools and models specifically conducive to ICM.

Although many useful recommendations are made in this document, this guide is not intended to present a rigid template to be strictly followed in all ICM applications. The varying characteristics of individual regions, corridors, deploying agencies, and ICM strategies virtually ensure that each AMS effort will be different in each ICM application. Users of the document are encouraged to modify and enhance the processes presented here to best meet their own needs. Finally, this guide is not a modeling tutorial. It is designed to provide guidance to managers interested in implementing the ICM AMS methodology. Lessons learned through these continuous improvement and customization efforts are further anticipated to add to the knowledge base for future assessments of ICM through the process of continuous improvement.

Companion Resources

The reader is encouraged to reference the following companion resources when using this Guide (all of these documents and additional helpful resources can be accessed through the searchable, browseable ICM Knowledgebase at http://www.its.dot.gov/icms/knowledgebase.htm):

- **ICM Fact Sheets:** Double-sided fact sheets provide visual summaries of ICM, the ICM Pioneer Sites, Demonstration, and the USDOT's ICM Initiative and knowledge and technology transfer resources.
- **ICM AMS Methodology:** Describes the AMS methodology applied to the three Pioneer Sites. This resource provides an in-depth presentation of "what" this methodology is, whereas this guide describes "how" to apply this methodology, incorporating the lessons learned from these applications.
- **ICM Implementation Guide**: This guide shares a similar structure to this ICM AMS guide, providing step-by-step guidance for the development and implementation of an ICM system (the first edition focusing on the CONOPS and requirements development phases). Users of the ICM AMS Guide will want to leverage and, ideally, actively contribute to the decisions regarding the CONOPS and requirements of the ICM system and associated strategies being analyzed.
- **Pioneer Site Analysis Plans (also called "Experimental Plans").** These analysis plans provide helpful real-world examples to readers of this guide. See also the summary of results from each of these Pioneer Sites.
- **FHWA Traffic Analysis Toolbox.** The Traffic Analysis Tools Program was formulated by FHWA in an attempt to strike a balance between efforts to develop new, improved tools in support of traffic operations analysis and efforts to facilitate the deployment and use of existing tools. FHWA has established two tracks under the Traffic Analysis Tools Program: the

deployment track and the **development track**. Visit the web site for more information: http://www.ops.fhwa.dot.gov/trafficanalysistools/index.htm.

- **National Highway Institute (NHI) course "Planning and Managing Successful Applications of Traffic Analysis Tools" (Course Number: 133108).** Two-day instructor-led course utilizing lecture and small-group collaborative exercises to train participants on how to use traffic analysis tools for transportation decision making. The course is designed to cover appropriate roles for traffic analysis tools; classes of analytical tools and their capabilities; managing the application of traffic analysis tools to support transportation decision- making, including planning for analysis, data collection, model validation and using the model to evaluate competing project alternatives. Visit the NHI website to learn more: http://www.nhi.fhwa.dot.gov/.

- **FHWA Resource Center training and technical assistance offerings.** The Resource Center Planning Technical Support Team and Operations Technical Support team both offer training and customizable technical assistance for various tools used in the AMS process. See http://www.fhwa.dot.gov/resourcecenter/teams/planning/index.cfm and http://www.fhwa.dot.gov/resourcecenter/teams/operations/index.cfm.

1.4 Organization of the Guide

This guide is organized into the following sections:

- **Chapter 1 – Introduction and Background** provides a high-level introduction to the ICM initiative and AMS methodology along with a discussion of the benefits.

- **Chapter 2 – Overview of Recommended Approach** summarizes the basic approach for implementing the ICM AMS methodology.

- **Chapter 3 – AMS Worksteps** provides a step-by-step framework for implementing the ICM AMS methodology.

- **Chapter 4 – Lessons Learned** summarizes lessons learned from the ICM AMS Pioneer Site experiences implementing the ICM AMS methodology.

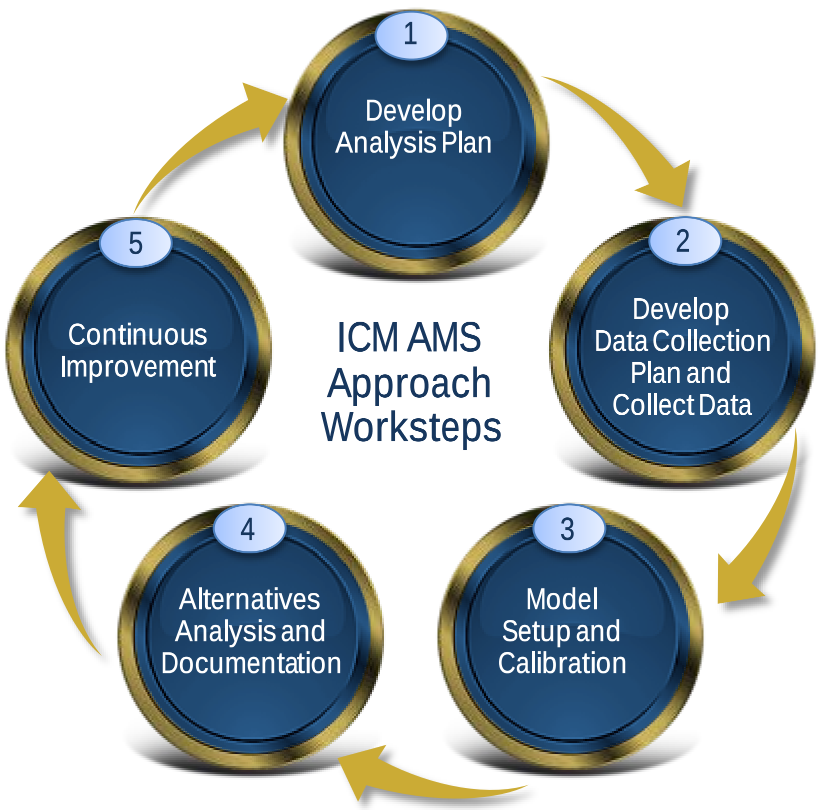
Each major workstep presents a summary of the objective, approach and substeps, deliverables, timeframe, and anticipated challenges. The worksteps incorporate and reflect the lessons learned from the three Pioneer Sites that implemented this methodology.

The guide includes enabling mechanisms for accomplishing the worksteps, tips, visuals (figures and tables), and examples and quotes from Pioneer Sites to bring a feel for real-world implementation of this guidance to the reader.

Chapter 2 Overview of Recommended Approach

Figure 2-1 presents the five major worksteps, summarized below, associated with implementing the ICM AMS methodology. [5] (This figure will be repeated throughout Chapter 3 as a roadmap through the worksteps.)

Figure 2-2.ICM AMS Approach Worksteps



[Source: Research and Innovative Technologies Administration, ITS JPO.]

The five ICM AMS worksteps include:

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[5] These worksteps are based upon a nine-step process developed for the FHWA *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*. Although the worksteps are consistent, they are not identical.

1. **Develop Analysis Plan** – The analysis plans developed as part of the ICM AMS methodology provide a valuable tool for communicating the scope of the project – a critical element—indeed, the foundation—of success in an AMS project. A team can expect to spend approximately 20-30 percent of the time investment on this step, which includes initial planning and scoping and then iterative updates to assumptions, scope, and agreements as the project moves forward. The development of the analysis plans is the primary mechanism for securing a clear and mutual understanding among stakeholders of expectations and assumptions. It may help to identify flaws or technical issues in the ICM CONOPS that may have been otherwise overlooked.

   The analysis plan confirms not only the stakeholder agreements regarding the scope of the ICM analysis, but also the most appropriate approach to the analysis based on an enhanced understanding of project objectives, the corridor conditions, the ICM strategies being implemented, and the available tools and data. The benefits of completing this workstep include a better allocation of resources appropriate to the study objectives; a clear and shared understanding of roles, responsibilities, and expectations among project participants; and the ability of project participants to effectively communicate the project vision to the broader stakeholders. It also helps maintain agreement and project continuity as stakeholders leave positions and new staff comes in mid-stream.

2. **Develop Data Collection Plan and Collect Data** – The purpose of this workstep is to collect the needed data to support the desired analysis cost-effectively. In this step, project partners research data needs and availability, identify available data as well as gaps and methods to address those gaps where possible, compile and archive needed data, collect data, and perform quality control on the collected data. This step represents approximately 10-20 percent of the total work effort for the AMS initiative. The successful completion of this task will support high-confidence AMS through the collection of appropriate, high-quality data using the most effective and efficient methods. Doing this well can substantially reduce costs both downstream and in continual process improvement.

3. **Model Setup and Calibration** – The purpose of this step is to configure the model(s) and tools to reflect the agreed-upon objectives, scope, and parameters of the AMS and to verify proper model calibration to support accurate results. Model setup and calibration represent approximately 30-40 percent of the total work effort for the AMS initiative. In this step, the baseline model network is developed, including all relevant transportation facilities and modes. Also, baseline demand modeling is conducted, and the simulation models are calibrated. This step also includes the testing the sensitivity of the model to better understand limitations of the analysis. This workstep can often be the most time- and resource-demanding of the AMS process. Successful completion of this workstep will ensure the integrity of the developed models and the efficient use of valuable resources, and will support risk management for this critical step.

4. **Alternatives Analysis and Documentation** – The purpose of this step is to identify the optimum combination of ICM strategies for various operational conditions[6] to support effective ICM. This step includes developing future baseline model networks and trip tables for all operational conditions and conducting the alternatives analysis for all ICM strategies. This step assumes that preliminary strategies/alternatives screening has already been performed using sketch planning or other iterative examinations. If all previous steps have been carefully executed, this step represents approximately 15-25 percent of the total work effort. The outcomes of this project will include an understanding of

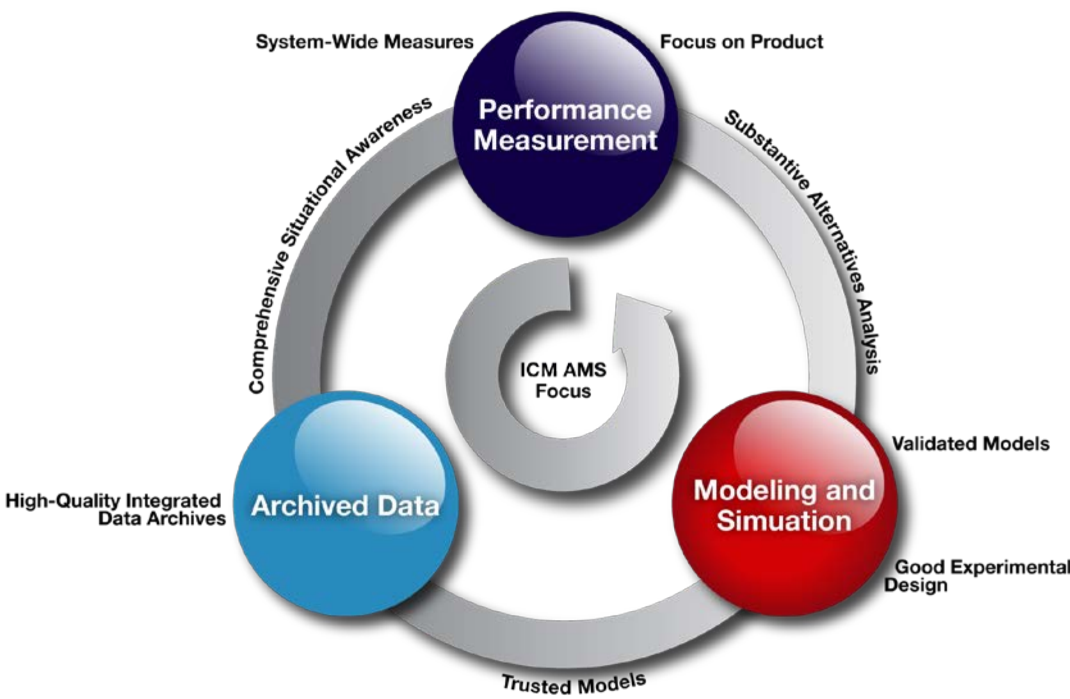
[6] Examples of operational conditions include roadway congestion and transit demand levels; incident conditions; weather conditions affecting operations; presence of work zones; special events.

predicted effects (including unintended consequences) for various hypotheses of interest, prioritization of ICM alternatives, and a quantified understanding of project benefits and costs. The results will inform ICM deployment decisions and can help build support among broader stakeholders for the ICM system.

5. **Continuous Improvement** – In this step, practitioners reassess models, model calibrations, and results against observed conditions to validate the AMS approach. Lessons learned are used to improve the process for future deployments, and ongoing performance measurement is used to refine the efficiency of the ICM. This step is ongoing, and consists of the repetition of this process in a manner that reflects and incorporates the data gathering and lessons learned from previous steps. This step represents approximately 5 percent of the total work effort.

AMS is not intended to be performed as a one-time, self-contained planning process. Instead, as shown in Figure 2-2, AMS is intended to be an ongoing, continuously improving process designed to assist practitioners in envisioning, designing, and refining ICM strategies.

Figure 2-3. Continuous Process Improvement for ICM



[Source: Karl Wunderlich, Noblis, 2010.]

In this continual cycle of trial and improvement, analytical capital is accumulated. This incrementally increasing knowledge base tends to be self-fulfilling because as improvements are discovered and implemented among the performance measures, modeling and simulation, and archived data processes and systems, further enhancements are encouraged by the resulting improvements in analysis capabilities and greater trust in the model processes and results.

Estimating Level of Effort

There are many variables that affect level of effort for any of these worksteps, including the existence of, and level of precision in, available ICM CONOPS documentation; quantity, quality and availability of needed data; cohesion in stakeholder vision for the AMS effort; and experience of the corridor staff with modeling tools in previous efforts, among others. Although each analysis will vary due to these factors, a rough order of magnitude estimate of the proportion of analysis resources that may be required of the different analysis steps includes:

- Develop Analysis Plan – 20-30% percent;
- Develop Data Collection Plan and Collect Data – 10-20 percent;
- Model Setup and Calibration – 30-40 percent;
- Alternatives Analysis and Documentation – 15-25 percent; and
- Continuous Improvement – 5 percent (in most cases this process is beyond the immediate project scope).

While the worksteps and substeps are presented sequentially, but in actuality the AMS process is iterative and requires flexibility in its application. The implementation of these steps and substeps will need to be carefully configured to the individual needs of each analysis effort and appropriately readjusted throughout the process as conditions and needs change. Chapter 3 describes the major worksteps and substeps in detail.

Enabling Mechanisms

Close coordination with an extensive set of project stakeholders is vital to the success of the ICM AMS initiative. The following are enabling mechanisms that facilitate the highly-collaborative process embodied by this ICM AMS methodology and utilized with success by the ICM Pioneer Sites. Project managers are encouraged to use and to factor them into resource allocation and planning timelines.

- **Technical Working Groups** – Technical working groups can focus on specific topics that require either consensus-based decisions (i.e., how and where to apply specific ICM strategies, etc.) and specific problems requiring solutions.
- **Research and Data Gathering** – The analysis plan (Workstep 1) and the data collection plan (Workstep 3) both require intensive research into available current and historical documentation from various agency partners along the corridor, including corridor studies conducted by public sector transportation agencies or private sector developers, long-range transportation plans, data from ITS, and crash reports, etc.
- **Site Visits** – A site visit to the corridor is a critical mechanism in creation of an effective analysis plan. Subsequent field visits will help to develop the supporting data collection plan. The site visit provides stakeholders with a tangible, physical understanding of the corridor and what it means to operate the corridor in a truly “integrated” fashion—an understanding that cannot be obtained through any other means. The site visit is the only mechanism that truly imparts the traveler perspective to the ICM AMS team. It is only through a site visit, for example, that stakeholders can see that plans to divert travelers off a freeway to certain transit stations would require investment in additional signage in order to be feasible; or that it may simply not be feasible to divert a high volume of travelers to another station that

may lack shelter or require a majority of travelers to make an additional transfer. The site visit should include travel on each and every mode for familiarity and observation.

An initial site visit should include a comprehensive review of all the different facilities (freeway and parallel arterial), as well as major mode transfer locations throughout the corridor and any regional transportation management center or toll facilities. Depending on the characteristics of the ICM strategies being considered, the project managers may want to plan to visit the site on multiple occasions (e.g., peak period vs. off-peak, or good weather vs. inclement weather) in order to gain further insight into how corridor traffic characteristics vary in relation to these factors. It is critical that the modeling team be in attendance. Some stakeholders may feel they are sufficiently familiar with the corridor since many may be in the field on a daily basis (for example, checking signals, etc.), but most agencies are likely familiar with only the aspects of the corridor that relate to the parts they manage and operate. They have not viewed the corridor through the eyes of another mode's perspective or as an integrated transportation system.

> The site visit provides stakeholders with a tangible, physical understanding of the corridor, and what it means to operate the corridor in a truly "integrated" fashion—an understanding that cannot be obtained through any other means.

- **Interviews** – Within the various stakeholder organizations there are likely to be individual practitioners who have a specialized understanding of specific current or historical aspects of the corridor.
- **Technical Memos** – Technical memos can serve as a valuable mechanism for documenting specific findings, agreements, plans and interim status reports as the ICM AMS initiative progresses. They can help support a clear and mutual understanding among stakeholders of the initiative, its status, and its expected outcomes. Technical memos typically have a specific focus and supplement the major deliverables described in this plan.

Chapter 3 AMS Worksteps

3.1 Workstep 1: Develop Analysis Plan

The analysis plan serves as the guidebook, or common "playbook" among all stakeholders, for conducting the AMS. It compiles project information and understanding developed to date and provides a single-source document for the AMS approach and methodology. The analysis plan needs to be sufficiently detailed to provide practical guidance on the actual conduct of AMS, yet it should also retain some flexibility to adapt to project contingencies as they are encountered. This is part of the continual improvement that is critical to AMS success. Development of the analysis plan is an iterative process. Project managers should plan for multiple versions of this plan as additional detail becomes available throughout the process and key assumptions need to be revisited. Because of its foundational role in scoping, shaping, guiding, and documenting the AMS effort, the efforts involved in accomplishing this Workstep receive special attention in this guide.

Objective and Value

The objective of this workstep is to research the analysis needs of the ICM alternatives and develop a sound analysis approach based on the operational conditions and the planned objectives of the ICM strategies. This analysis approach, including identification of appropriate tools and modeling methodologies, will be defined in the analysis plan. The development of an effective analysis plan is absolutely critical for success in complex projects such as ICM to ensure the analysis can be properly assessed with the resources available.

There is significant direct value in completing development of the analysis plan, which:

- May help to identify flaws or technical issues in the implementation plan or CONOPS that may have been otherwise overlooked;
- Provides a valuable tool for communicating the scope of the project, which is a critical element in promoting the success of the ICM project;
- Enhances opportunities for success by identifying project challenges and planning mitigation for those risks;
- Helps to identify and prioritize resources to project objectives, allowing for the effective and efficient allocation of resources and more sound project management;
- Provides an enhanced understanding of existing corridor conditions and deficiencies, allowing for the improved ability to match and configure proposed ICM strategies to the situation at hand;
- Helps to appropriately set expectations of different project participants (e.g., planners, operators, data analysts, modelers, and agency management), and provides clearer definition of expected roles and responsibilities;

- May be utilized in an iterative manner with the design process to better refine final alternatives;
- Documents the analysis planning process for use in future applications.

> "Many stakeholders naturally focus on the specific area of a corridor for which they are responsible. They may think, 'I've done a site visit—I drive through my signals every day checking on them.' But they haven't yet seen the corridor from ICM perspective—bringing transit, signal, freeway folks together to look at the corridor as a system."
>
> James Colyar,
> USDOT ICM Initiative Technical Liaison,
> FHWA

The development of the analysis plan usually begins in the early stages of the ICM planning effort, often in parallel with the development of the deployment CONOPS and requirements. ICM AMS stakeholders may overlap with those developing the CONOPS and requirements for an ICM system. It is a good practice to conduct these activities in parallel where possible and to collaborate closely throughout the scoping phases of each of these related efforts.

The CONOPS and requirements documents and the analysis plan are not developed through a one-time meeting or single conversation. They are produced throughout the course of a series of ongoing conversations that share the outcome-oriented objective of defining the vision and components of the ICM concept as precisely, and with as much specificity, as possible. The AMS stakeholders (particularly modelers) are likely to ask more detailed questions than those developing the CONOPS may initially consider because CONOPS developers are working at the concept level, developing broad outlines of the potential ICMS. For example, the ICM CONOPS may reflect the planned inclusion of available parking strategies. At some point, the AMS team will likely inquire into the specific information about parking availability, the specific envisioned locations of the ramp meters along the corridor, etc.

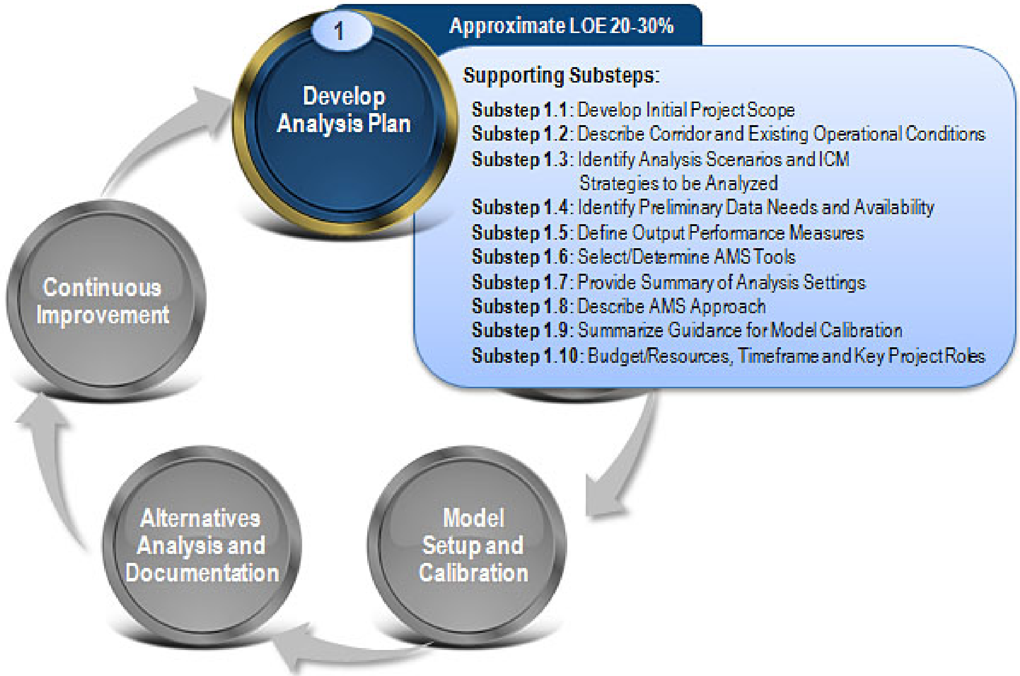
> **TIP:** Develop the analysis plan in close collaboration with, and ideally in parallel with, the ICM CONOPS and requirements documents.

It is critical that the analysis plan not be completed until the full definitions of the anticipated ICM strategies are finalized; the strategies to be analyzed must be known prior to the finalization of the analysis plan. Often, the analysis plan continues as a "living document" throughout the analysis lifecycle and is continually updated as assumptions change and new information is learned, serving as documentation of changes made throughout the analysis.

Approach and Substeps

Figure 3-1 presents an overview of the substeps related to the development of an analysis plan. The output resulting from completion of each substep maps directly to the development of the analysis plan, (see example outline shown in Table 3-1). The reader is encouraged to review the analysis plans of the three Pioneer Sites as references. Subsequent discussions provide additional detail recommended for conducting the identified substeps.

Figure 3-4. Overview of Workstep 1: Develop Analysis Plan



[Source: Research and Innovative Technology Administration and Cambridge Systematics.]

Table 3-1. Example Outline for Analysis Plan

Example Analysis Plan Outline
1. Introduction and Initial Project Scope: a. Corridor Overview b. Project Background and Guiding Principles c. Project Goals and Objectives d. Process for Developing and Applying the Analysis Plan
2. Corridor Description and Existing Operational Conditions
3. Analysis Scenarios and ICM Strategies
4. Data Needs and Availability
5. Output Performance Measures
6. AMS Tools and Selection Methodology
7. Summary of Analysis Settings
8. Summary of AMS Approach
9. Guidance for Model Calibration
10. Budget, Schedule and Key Responsibilities a. Budget/Resources a. Schedule/Timeframe a. Key Project Roles/Responsibilities

Substep 1.1: Develop Initial Project Scope

Note: Completion of this substep correlates with and helps to populate Sections 1 and 2 of the analysis plan, "Initial Project Scope," and 2, "Corridor Description and Existing Operational Conditions."

TIP: Creating a visual corridor timeline noting major infrastructure developments/expansions, new influences, etc., can be helpful in understanding the evolution of the corridor.

The AMS Project Team will conduct an internal kickoff meeting to initiate project scoping prior to engaging a broader group of stakeholders. The outputs from this meeting should be considered preliminary as they will evolve significantly based on the input from stakeholders and technical working groups throughout the course of the development of the analysis plan. The core team can begin to outline the broad parameters of the following scoping elements for the AMS effort:

a. Develop Corridor Overview– A first step in scoping an ICM AMS initiative consists of developing an overview of the ICM Corridor. An overview description of the corridor site should be developed and should define the geographic boundaries of the analysis corridor. This can be taken directly from the ICM CONOPS document, and if the analysis plan is being developed in parallel, the AMS team will ideally be working closely with the ICM CONOOPS team. Using text and annotated GIS and/or illustration visuals to describe the corridor as robustly as possible will aid subsequent AMS scoping decisions and provide a strong foundation for a clear and mutual understanding among stakeholders. The corridor overview should include geographic boundaries of the corridor, a high-level description of current or planned modal facilities, as well as descriptions of key influences (business, residential, etc.) affecting transportation patterns in the corridor.

TIP: Use the stakeholders involved in the ICM CONOPS as the starting point for identifying potential stake-holders to invite to the process.

b. Project Background and Guiding Principles–Providing a brief description of the project background, including the rationale for the decision to invest in ICM and ICM AMS, can help to secure stakeholder engagement and equip these stakeholders to build support within their agencies for the initiative. A high-level description of the need for the ICM strategies and documentation of the high-level AMS project goals should be developed based on those outlined in the ICM CONOPS.

Guiding principles help stakeholders and outside interests better understand the focus and boundaries of the AMS for the project, and help to assure any key stakeholder concerns will be honored as part of the process. An example of a key principle that should be applied in all AMS includes: "The overall AMS effort must take place within the budget and timeframe specified in the analysis plan."

Enabling Mechanisms:

- Kickoff Meeting
- Background research
- Coordination with ICM CONOPS and Requirements team

Finally, the AMS team is encouraged to outline an envisioned plan for continuous process improvement (see Workstep 6). While the planning steps defined in the following pages are designed to result in an effective approach for implementing the ICM AMS methodology, there is no way that an AMS manager can accurately anticipate all the needs of the study at this early phase. Therefore, it is critical that a change management process be thought out at this early stage, and that stakeholders collectively commit to this as a priority in order to mitigate the negative impacts of project changes and provide for continuous improvement to the AMS as the analysis moves forward. The description of this should also include how lessons learned from the process will be documented and change will be managed to improve the project continuously and to add to the knowledge base for future analyses.

c. Determine Project Objectives and Needs – The overall goals and objectives for the ICM strategies being considered in the corridor's ICMS should be assessed and used to shape the goals and objectives of the AMS effort. A clear definition of the "what" and "why" for conducting the analysis will provide a foundation for the analysis plan. The objectives should be "SMART" (**s**pecific, **m**easurable, **a**ctionable, **r**ealistic and **t**ime-bound). To the extent that these objectives can be defined in a manner that can support an eventual ICM cost-benefit assessment, this can help to secure stakeholder support for the AMS effort.

The project partners should carefully review the ICM CONOPS and requirements documents to ensure the objectives established for the AMS effort are consistent with the goals and objectives established for the ICM effort. The ICM AMS team is ideally a key participant in meetings associated with the development of the CONOPS and requirements documents if these are being developed in parallel with the analysis plan. If they were developed previously, the AMS team should seek to engage these stakeholders in the analysis plan scoping meetings. The objectives of the AMS should fully support and be consistent with the overall goals for the deployment project. As noted earlier, this may evolve through the course of subsequent meetings and/or site visits and should be updated as needed as the analysis plan progresses.

d. Determine a Process for Developing and Applying the Analysis Plan – Identifying a complete set of stakeholders who fully represent the agencies and organizations impacted by the ICM is critical. (The AMS team is encouraged to build on the stakeholder set identified for the ICM CONOPS and requirements effort). This will include representatives of agencies from different jurisdictions managing parts of the corridor components and modes impacted by the strategies (e.g., highway or roadway agencies, transit agencies, ICM program managers/stakeholders, freight industry groups, bike/pedestrian groups). Developing a stakeholder database from the beginning can be helpful and can provide a mechanism for tracking contact information, special concerns, and stakeholder engagement. At a minimum, it can be helpful to track stakeholders by name, organization, segment (State/local/private sector), title, role on ICM AMS project, mailing address (with State, city/county noted in manner that can be sorted), and the individual's contact information. AMS stakeholders may include more technical stakeholders and could also likely include some nontraditional members, such as emergency responders, toll authorities and media representatives, depending on the priorities and objectives of the overall ICM system for the corridor. Once the stakeholders are identified, the group will then agree on a process for developing the analysis plan—this may include technical working groups supplemented with periodic meetings with the full set of stakeholders. It may be helpful to document this process in a memorandum of understanding signed by stakeholder organization leaders.

TIP: Request that stakeholders bring a list of relevant documentation (and links) to the initiative kickoff meeting.

Substep 1.2: Define Corridor and Existing Operational Conditions

Note: The output of this substep will populate Section 2, "Corridor Description and Existing Traffic Conditions," and will support completion of Section 3, "Analysis Scenarios and ICM Strategies," of the analysis plan.

To complete preliminary scoping, the project team will conduct a kickoff meeting with all stakeholders to further scope the AMS initiative. This meeting provides the opportunity to gauge and further deepen stakeholder commitment to the ICM AMS effort and to obtain input regarding stakeholder perceptions of project needs and expectations, including ICM and AMS.

TIP: Plan early for continuous process improvement.

In this meeting, the project managers will review the preliminary corridor overview, their initial inputs regarding the vision of the ICM AMS, critical stakeholders, and the ICM AMS goals and objectives and project background, and will solicit additional input from the broader range of stakeholders. Desired outcomes from this kickoff meeting include consensus-based agreement among stakeholders on the general process, and the timeline, roles, and responsibilities associated with the envisioned ICM AMS effort, which will include the steps needed to confirm project scoping and the analysis plan overall (such as site visits, documentation research, data gathering, etc.).

Through the kickoff meeting and other preliminary activities, stakeholders will further refine the scope the ICM AMS initiative by exploring the following example questions:

- What is the appropriate geographic scope for the analysis (corridor boundaries)?
- What facility types need to be included in the analysis (description of freeway and arterial facilities (including general roadway geometrics such as number of lanes), HOV facilities, existing tolled facilities, etc.)?
- What travel modes need to be included in the analysis (transit and multimodal facilities) to include any major mode transfer locations (e.g., park and ride lots)?
- Are there any relevant existing ITS or operations deployments (e.g., variable message sign locations)?
- What are the ICM strategies to be implemented?
- How were the included ICM strategies selected?
    - Were there other strategies that were considered that weren't ultimately selected? Why not?
- What analysis, if any, has been completed to date to assess either the needs (i.e., problem documentation) or the high-level potential effectiveness of the selected strategies (e.g., results from previously conducted sketch planning analysis of the potential impacts of the possible strategies)?
    - What were the methodologies and outcomes of these efforts?
- What are the expected traveler responses to the ICM strategies?
- What performance measures need to be produced by the analysis?
- What is the approximate budget and timeframe for the AMS work?

Existing traffic conditions should also be documented, including but not limited to:

- Average daily and peak traffic levels;
- Directionality of traffic flow;
- Variability of traffic flow;
- Status of construction activities;

- Known bottlenecks;
- Queuing conditions;
- Free flow and average peak speeds; and
- Summary incident and accident statistics for the corridor.

In documenting existing corridor and traffic conditions, it can be useful to analyze and document the factors that influence congestion in the corridor (e.g., frequency of special events in the corridor). This analysis activity will eventually feed into the identification of analysis scenarios completed in a subsequent substep. The analysis of influencing factors can include demand variations, corridor incidents, or weather. This analysis helps project analysts and stakeholders to better understand the causes of congestion in the corridor and the frequency with which these causal events occur.

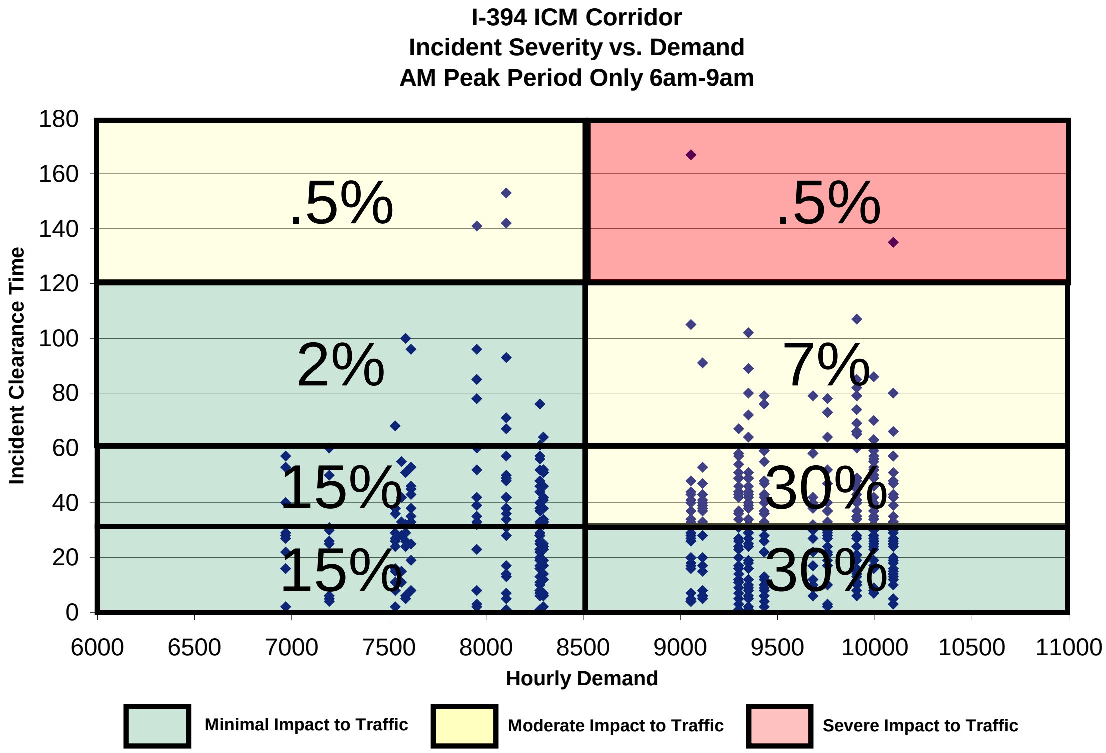
Stakeholders will first address these questions qualitatively through the course of the Initiative kickoff, site visits, interviews and related subsequent meetings. Later, as available data is gathered and compiled, stakeholders will flesh these answers out where possible based on quantitative analysis. Data related to these factors can be compiled and analyzed to illustrate the effects of the factors on existing traffic conditions in the corridor.

Key outcomes of the assessment of the corridor and existing operating conditions can be thought of as a "problem definition" and a "problem diagnosis". In many cases, the problem definition will already be defined and documented as part of the CONOPS work completed to this stage. The ICM AMS team should carefully evaluate any needs assessments and problem definitions included in the CONOPS to see that they are consistent with the existing conditions data and material compiled. If a modified or more discrete problem definition is required, the ICM AMS team, led by the manager, should work closely with the ICM CONOPS development team to firmly define the problem being addressed. The problem diagnosis should include a more thorough assessment of the corridor conditions to ensure that the needs are properly defined. Reviewing analysis results from previously conducted assessments and comparing these with high-level assessments of existing conditions data should assist in identifying the likely causes and extents of the identified problem. Additionally, the ICM AMS team should carefully assess any project goals and objectives identified to date and map these to the problem diagnosis to evaluate their applicability. For example, if one of the stated objectives of the ICM project is to address congestion during special events, yet the assessment of existing conditions reveals that very little congestion may be traced to periods of excessive demand during special events, this discrepancy should be highlighted and brought to the attention of the ICM CONOPS team for possible reconsideration.

> "Building the AMS Analysis Plan allows stakeholders to explore questions such as, 'We have opportunities for considerable optimal mode shift in this area based on preliminary analysis—what do we need to make mode shift really feasible and attractive?'
>
> Robert Sheehan,
> USDOT ICM Initiative Demonstration Site Liaison, FHWA

Figure 3-2 presents an example of how this information can be visually displayed. In this example, a scatter diagram that shows the combined impact of various demand levels and incident clearance times mapped to the resulting traffic congestion impact on the I-394 corridor in Minneapolis. This visual illustrates that in this corridor, the highest levels of congestion were observed to occur on high-demand days when an incident requiring more than 2 hours to clear occurred in the corridor. However, this visual also shows that these high-demand/high-incident severity events make up a very small overall proportion (one half of one percent) of all corridor incidents. Corridor managers realized it would be important to determine whether the impacts from this small number of incidents were disruptive enough to merit investment of ICM and AMS resources.

Figure 3-2. Example Scatter Diagram Comparing Impacts of Demand and Incident Severity on the I-394 Corridor in Minneapolis



[Source: Cambridge Systematics, September 2008.]

Beginning to assemble and evaluate influencing factors in this way provides the opportunity to identify the best combinations of multiple scenarios that are most representative of actual conditions.

> *"The questions that the modeler and the operator ask are not that different. The modeler's questions are just more detailed as they come earlier in the process."*
>
> Vassili Alexiadis, Program Manager for the Pioneer Site AMS initiative, Cambridge Systematics, Inc.

This information can be used to define analysis scenarios (see subsequent Substep 1.3) that make the best use of analysis resources. This allows analysis resources to be targeted towards appropriate scenarios that neither under- nor over-estimate the impacts of the ICM strategies. This resource allocation is typically accomplished through the allocation of the number of model runs to various scenarios. For example, the AMS team may note that inclement weather days make up a very small percentage of the overall travel days in a warm weather location; therefore, it may be decided to eliminate weather as a separate analysis scenario factor, freeing up modeling resources to better focus (i.e., run more scenarios) on varying incident conditions.

Substep 1.3: Define Analysis Scenarios and ICM Strategies to be Analyzed.

Note: The outputs from this substep, when it is sufficiently precise, will shape and refine Section 4, "Data Requirements," Section 5, "Output Performance Measures," and Section 6, "Analysis Methodology and Modeling Approach" (including the criteria and data requirements for model calibration of the analysis plan).

Once an initial understanding of the corridor and its operating characteristics has been defined, stakeholders will refine their understanding of the corridor in light of its major transportation issues. These issues will form the foundation for analysis scenarios and ICM strategies likely to be considered in the AMS analysis. Note again that the analysis will be mostly qualitative at this stage. The developed ICM CONOPS and requirements documents are particularly useful pieces of information to continually review and reference throughout this workstep to ensure consistency with the ICM strategies being planned.

Analysis scenarios will be developed based on understanding of the corridor's geographic scope; infrastructure and facilities; causes and patterns associated with recurrent congestion (i.e., capacity, weave zones, etc.) and non-recurrent congestion; and specific causes of non-recurrent congestion, such as traffic incidents (i.e., incident characteristics: number of incidents per day in corridor, number of lanes blocked, response time, high frequency crash locations, root cause where known (i.e., merge or weave zones, lane drops, physical characteristic such as a blind curve, etc.), incident response protocols for various incident types, etc.). The corridor problem definition and diagnosis documented in the assembly and analysis of the existing conditions completed in the previous steps form the foundation for the identification of suitable alternatives.

Although the alternatives identification discussed in this section is presented as a singular process, in reality this is not typically a linear process. The initial alternatives identification takes place in close concert with the design phase – formulating likely ICM strategies and combinations of ICM strategies based on the operational plans defined in the CONOPS and mapping these to the existing conditions outputs generated in the previous stage. As the analysis continues and the initial results are reviewed and shared with the design team, it is likely that some modifications or new alternatives may be proposed, as certain alternatives are found to be impractical or result in unforeseen negative impacts. For example, an analysis of an ICM strategy may reveal that the strategy is creating a bottleneck at a downstream location that wasn't foreseen prior to analysis. This unexpected result may promote a change in the strategy that may cause the analysis to be re-run for alternatives containing the strategy. In reality, the alternatives definition and design process will continue in an iterative manner throughout the process.

Scenarios should be developed for the range of operational conditions of greatest interest to the site in light of its analysis objectives. For example, while traffic incidents are the single largest cause of non-recurrent congestion, stakeholders are encouraged to investigate and understand other influences, including special events, weather, fluctuations in demand, and work zones.[7] This initial analysis will also include developing a preliminary understanding of both supply side (infrastructure/capacity) and demand-side influences on the corridor across all modes (including underlying causes of demand such as directionality, day of week, etc.), with a goal of beginning to identify potential issues (where demand exceeds supply to an extent believed to interfere with corridor performance) and opportunities (underutilized capacity/supply that could potentially help absorb demand).

Practitioners should compile data on the frequency and severity of conditions linked with elevated congestion levels. As exampled previously in Figure 3-2, comparisons or distributions of various sources of delay should be assembled and evaluated to identify the relative frequency of events/conditions related to congestion. From this assessment, practitioners should critically assess the potential impact of various scenarios. Scenarios identified as having a low frequency of occurrence or likelihood should be considered for removal from the analysis effort, or at least assigned with a low-priority, since the impact of their inclusion, which should be weighted by their low likelihood of occurrence in the analysis, will likely provide much less impact on the final analysis outcomes than scenarios with more significant frequency of occurrence. This problem diagnosis analysis may reveal needs previously unknown to the practitioners, help to weed out inconsequential

[7] The top causes of non-recurring congestion are traffic incidents, special events, weather, fluctuations in demand, and work zones.

scenarios, and will greatly assist in targeting resources to provide the greatest expected value from the analysis.

The data analysis required in this step includes the identification of the frequency and likely impact of the scenario. Those scenarios recording the greatest frequency and the greatest impacts should be given the highest analysis priority. Scenarios with a low likelihood, but major impact (e.g., major snowstorms), OR scenarios with a frequent occurrence, but limited impact (e.g., minor incidents occurring on otherwise normal days) should be provided slightly less priority. Scenarios with low frequency and low impacts should be considered for deletion from consideration. There are no set thresholds for the inclusion or dismissal of scenarios. The AMS team will need to apply engineering judgment and common sense to this process.

Interviews with project partners also can also be invaluable in understanding corridor conditions and the strategies being considered. In addition to any available ICM CONOPS and Requirements documents, the following types of documents can provide valuable insight into the current operational characteristics of the corridor: previous corridor studies, transit data and studies on topics such as ridership and parking occupancy (supply and demand); archived data systems (ITS); and crash/incident data reports. Regional and long-term transportation plans provide insight into congestion hotspots, but these must be supplemented by more detailed corridor studies.

The project managers should also seek out information on the ICM strategies being considered and the impact these strategies have had in other regions. Likewise, developing an understanding of previous capacity and/or operational strategy projects in the corridor—including an understanding of the expected and unexpected results of those projects, can be beneficial. Peer-to-peer contact with agencies that have undergone ICM planning and deployment is a valuable way to gain this insight.

TIP: Corridor operators may not be accustomed to working with modelers, who ask very specific questions they may not feel prepared to answer. It can help to prepare stakeholders for this phase of the process, and to remind them that beginning to talk at this level of detail is critical to eventual ICM deployment decisions.

Once the scenarios have been identified, the next step in this process is to identify the ICM strategies and define under which analysis scenarios the strategies will be activated. The AMS team should consult with the ICM CONOPS Requirements, and discuss the operating strategies with the operational managers and personnel to map the ICM strategies to the appropriate analysis scenarios.

It is also critical to understand precisely when (i.e., under what conditions) the strategies will be applied and how their application may vary under different conditions. The project managers along with the stakeholders need to identify the combinations of travel demand, incidents, special events, and weather events that affect corridor operations to better understand what factors influence congestion and the frequency in which these factors occur. An ICM deployment project will likely be concerned with nonrecurring congestion on a level equal to or greater than typical recurring congestion levels, because these are the areas where the benefits of ICM are greatest. Therefore, it is critical that the AMS team recognize the non-typical factors that impact nonrecurring congestion.

TIP: This initial qualitative analysis requires developing more than a generalized understanding of the corridor's needs and patterns—not merely identifying average spare capacity but spare capacity associated with specific origin and destination locations, time, and operating condition(s).

The AMS planning team will begin by exploring preliminary scoping hypotheses and assumptions and identifying possible opportunities and constraints associated with the application of ICM strategies identified under specific operational conditions (these scoping assumptions are initial and preliminary in nature and will all be refined further in Sections 3, 6, and 7 of the analysis plan). For example, freeway managers may be

> *"ICM requires more than agreement in principle. It requires agreement in detail. AMS helps to resolve the agreement in detail."*
>
> Karl Wunderlich, Senior Modeling Expert, Noblis

interested in opportunities to divert drivers from the freeway to arterials as an incident management strategy. They will engage local arterial managers to understand whether the local jurisdiction can accommodate this diversion and activate these strategies to accommodate the desired corridor performance in a sufficiently timely manner. This should also include discussion of the potential to avoid problems – such as changing signal timing or VMS to avoid queues that may lead to collisions at critical locations. If there are contributing circumstances that can be avoided that lead to greater non-recurrent congestion, the team must devise strategies that may avoid these contributing circumstances. They will also seek to understand and address any concerns or constraints the local jurisdiction may have (i.e., is the technology in place to accommodate the needed signal timing, can the timing strategies be activated in a sufficiently timely fashion to make the strategy feasible).

Likewise, if corridor managers are interested in exploring opportunities to divert freeway or arterial traffic to transit, they will engage in collaborative dialogue with the regional transit managers to understand possibilities for creating available transit capacity, including parking facilities, to accommodate the possible influx of demand under certain scenarios.

These discussions will also begin to yield initial insights into the eventual performance measures for the ICM AMS effort. Because the models have not yet been run, these are preliminary scoping discussions at this phase, the purpose of which is to begin to shape possibilities and identify limiting factors that will form the foundation of the more detailed planning documented in the analysis plan. As these discussions progress and more quantitative data becomes known, stakeholders will update and refine assumptions and hypotheses, bringing further clarity and detail to the hypotheses and assumptions associated with the operational conditions and ICM strategies to be analyzed. The AMS planning team will want to identify which parts of the envisioned ICM strategies they may want to make dynamic (i.e., strategies that could be manipulated in response to changing operational conditions, such as ramp metering, HOV, or pricing strategies, or traveler behavior such as mode choice).

Table 3-2 shows an example high-level mapping of ICM strategies to analysis scenarios selected for the U.S. 75 corridor in Dallas. The Dallas ICM analysis plan describes these strategies and conditions regarding their application of these scenarios in detail. In this example, managers wanted to model the assumption that they would activate their smart parking system in the event of a major incident under medium and high demand conditions.

Table 3-2. Summary ICM High Priority Strategies for U.S. 75 in Dallas

Scenario	Daily Operations – No Incident		Minor Incident		Major Incident		
Demand	**Med**	**High**	**Med**	**High**	**Low**	**Med**	**High**
Traveler Information							
Comparative, multimodal travel time information (pre-trip and en-route)	●	●	●	●	●	●	●
Traffic Management							
Incident signal retiming plans for frontage roads			●	●	●	●	●
Incident signal retiming plans for arterials			●	●	●	●	●
Managed Lanes							
HOT lane (congesting pricing)	●	●					
Express toll lane (congestion pricing)	●	●					
Light-rail Transit Management							
Smart parking system						●	●
Red line capacity increase						●	●
Station parking expansion (private parking)						●	●
Station parking expansion (valet parking)						●	●

References to the ICM strategies these stakeholders decided to analyze are in the far left column. The three major columns to the right summarize three incident-related scenarios that would be examined under varying demand scenarios: daily operations/no incident, minor incident, and major incident. Note that this is an "at-a-glance" visual summary table only. The shaded dots indicate strategies that would definitely be activated in the event of the indicated operational condition scenario. Whereas this section of the analysis plan will be very detailed, a summary chart such as this can help stakeholders maintain an understanding of the "big picture" regarding which strategies under which operational conditions generally will be analyzed.

> *"In analysis, modeling and simulation one must rely on archived data, not on people's perceptions of congestion problems."*
>
> Vassili Alexiadis, Program Manager for the Pioneer Site AMS initiative, Cambridge Systematics, Inc.

It is important to remember that the analysis plan is a "living" document, and as mentioned in the introduction, its development is an iterative and highly collaborative process among project stakeholders. Ultimately, it is critical that these scenarios and ICM strategies are defined in sufficient detail to permit meaningful modeling.

Substep 1.4: Identify Preliminary Data Needs and Availability

Note: The output of this substep will further help to scope the anticipated level of effort needed to complete the ICM AMS based on available data relative to the project's objectives. It will also generate initial insights that will support completion of Section 4, "Data Requirements," of the analysis plan.

AMS managers and stakeholders should begin to explore potential data needs and sources for the analysis plan and the eventual data collection plan early, as data availability will be a key variable that may impact scope. The quality of the AMS analysis will be limited to the specific aspects of the corridor for which data are available. The analysis of data needs and availability is very preliminary at this stage, and will be further refined in the data collection plan (see Workstep 3).

In this step, datasets that will need to be compiled to support the AMS effort should be identified. Ideally, much of the required data will have been previously collected and archived, thus reducing the amount of analysis resources that will need to be expended for data collection. Encouraging stakeholders to come to the stakeholder kickoff meeting with preliminary lists of potential data and data sources is a good first step. For the analysis plan, only a high-level description of the required data is necessary; however, more detailed information (such as dates, times, locations, transit routes, etc.) may be provided if desired. See the Pioneer Site analysis plans for examples of the appropriate level of detail of the documentation of data needs for the analysis plan.

This initial review of data needs and sources should include both “traditional” and “nontraditional” data sources so that a comprehensive set of data that may be available for the project. “Traditional” and “nontraditional” labels are subjective, and perspectives on what constitutes these will vary by corridor stakeholder. Data on weather, demand patterns, and parking availability at transit stations may be considered traditional to agencies that work in these domains but nontraditional for other stakeholders. Consolidated reconstruction of specific traveler information messages disseminated via various mechanisms and the alignment of this information with operational condition information within a contemporaneous timeframe can provide an aggregated, comprehensive, multiagency view of corridor dynamics under a specific operational condition (e.g., a traffic incident).[8] This robust view is not “traditionally” constructed by any single agency.

For AMS needs, archived automated data sources (e.g., traffic detectors) are often more desirable sources of data than manually collected data. The availability of automated data representing different operational conditions (e.g., varying demand, incident, and weather conditions) provides additional opportunity to assess multiple operating conditions effectively. Archived data provides a longer-term perspective on problems such as bottlenecks. It allows analysts to see the congestion pattern “occur, grow, shrink, and disappear; not just over one day but over many days,” as Karl Wunderlich, Senior ICM AMS Technical Advisor, Noblis, explains.

Data from the multiple sources must also be for concurrent periods in order to neutralize seasonal and other travel pattern variances that can affect data. For example, data representing traffic conditions on the freeway during summer should not be compared with transit operating data collected during another time of the year.

The data should be collected from all sources for the same simultaneous period. For each data source, the AMS managers should ascertain:

- Time periods when the data is available;
- The format of the data;
- Any time lags in data availability (e.g., is accident data available immediately or is time required to record the data into a common database?);
- Whether the data are sufficiently detailed and specific for analysis purposes;

[8] Traveler information dissemination mechanisms can include variable message signs, media, DOT web sites, etc. Operational condition information could include incident management information and adjacent transit demand in a specific geographic travel shed.

- Reliability of the data sources (e.g., are there significant gaps in the data?); and
- Any known data quality issues (e.g., are there any operating conditions that cause the data to be inconsistent?).

Data reflecting traffic conditions should be explored in the kickoff meeting as well as data sources representing environmental conditions, operating conditions, and the implementation of operations strategies (e.g., logs detailing the operation of variable message signs). Whenever possible, actual samples of the data sets should be requested and obtained to efficiently assess the data sources. Reviewing examples of the Pioneer Sites' data collection plans will provide ideas for organizing this information in a manner that will facilitate efficient use downstream in developing the Data Collection Plan.

Substep 1.5: Define Output Performance Measures

Note: Completion of this step will populate Section 5 of the analysis plan, "Output Performance Measures."

In this substep, the AMS team will begin to define ICM-related performance measures in line with the objectives, ICM strategies, scenarios and operational conditions (shaped by the understanding of available data) identified for the AMS project. (Performance measures are defined in greater detail under Workstep 4, "Alternatives Analysis and Documentation.") This substep provides the "home" for where these are documented in the analysis plan, and helps the AMS team to crystallize its vision and scope for the AMS effort, and will help inform tool selection. This, as with all steps, is an iterative step, and the AMS team will need to revisit and refine these as the project moves forward.

Note that the performance measures and performance-based hypotheses defined here for the purposes of AMS are hypothetical. Sites are concerned about documenting expected performance of a system as dynamic, complex and largely experimental as ICM. However, in order to begin to understand how the ICM system will perform and whether it will meet stakeholder expectations, and even to help stakeholders develop realistic expectations for the ICM system, managers must first be willing to articulate them. The AMS effort will help to illuminate which expectations are realistic, which may be unrealistic, and why. It will help illuminate opportunities to optimize the corridor's overall transportation network by allowing analysis to experiment with adjusting ICM strategies for the price of a model run, rather than myopically make such adjustments to the actual deployed ICM system, where the cascading second and third-order effects are more difficult to perceive in real-time.

> *"AMS engages ICM partners in conversation around what it really means to operate the transportation system differently."*
>
> Robert Sheehan,
> USDOT ICM Initiative Demonstration
> Site Liaison, FHWA

The performance measures should be closely tied to the identified overall ICM project goals and objectives and the expected traveler responses. For many ICM strategies, it is important to consider a set of performance measures that are sensitive to recurring as well as nonrecurring congestion. The analysis plan should identify the selected performance measures as well as the approach for calculating the performance measures based on the expected model capabilities and available data.

An effective way to identify appropriate performance measures is to develop one or more specific hypotheses to be tested for each objective. These hypotheses can either indicate a change in travel conditions, such as, "The ICM strategies will reduce travel times during inclement weather by 5 percent," or can be neutral in the prediction of an impact, such as "The ICM strategies will not result in a change in corridor accident rates." Performance measures that support the testing of the formulated hypothesis should then be identified. Use of this method ensures that the performance measures are appropriately mapped to the project goals and objectives.

To be able to compare different investments within a corridor, it will be important to define and apply a consistent set of performance measures. The performance measures should:

- Provide an understanding of travel conditions in the study area;
- Demonstrate the ability of ICM strategies to improve corridor mobility, throughput, and reliability based on current and future conditions; and
- Help prioritize individual investments or investment packages within the corridor.

To the extent possible, the measures selected should be reported by:

- Mode – SOV, HOV, transit, freight, etc.;
- Facility Type – Freeway, expressway, arterial, local streets, etc.; and
- Jurisdiction **–** Region, county, city, neighborhood, and corridor-wide.

ICM-related performance measures selected will typically focus on the following four key areas described below. However, customized measures may be selected based on unique impacts of individual deployments. The four key ICM performance areas are:

- **Mobility.** Mobility describes how well the corridor moves people and freight. Mobility performance measures are readily forecast. Three primary types of measures were used to quantify mobility, including travel time, delay, and throughput. Travel time and delay are fairly straightforward to calculate using model outputs. Throughput was calculated by comparing travel times under the incident scenarios to those under no incident – by comparing the percentage of trips under the same threshold travel time in both the pre- and post-ICM scenarios, the relative influence of ICM on reducing extreme travel times can be estimated.
- **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 mobility varies from day to day. Travel time reliability/variability is reported in terms of changes in the Planning Index and changes in the standard deviation of travel time.
- **Emissions and Fuel Consumption.** Emissions and fuel consumption rates were used to produce estimates based on variables, such as facility type, vehicle mix, and travel speed.
- **Cost Estimation**. Planning-level cost estimates included life-cycle costs (capital, operating, and maintenance costs). Costs were expressed in terms of the net present value of various components. Annualized costs represent the average annual expenditure that is expected in order to deploy, operate, and maintain the ICM improvement and replace equipment as it reaches the end of its useful life.

A final performance area that may be of interest to corridor managers, safety, is not included in this list**.** Available safety analysis methodologies are not sensitive to ICM strategies. At best, available safety analysis methods rely on crude measures, such as V/C, and cannot take into account ICM effects on smoothing traffic flow. Clearly, this is an area deserving new research. As such, no safety analysis was conducted as part of this effort.

Appendix A provides an example of the level of detail and specificity in defining ICM performance measures required to understand the basis of calculation for the performance measures. The example performance measures included in this document were developed in the course of in-depth work the 8 ICM Pioneer Sites under the USDOT guidebook. This Appendix is provided as a resource for consideration to readers of the AMS Guide.

Development of ICM AMS performance measures is an iterative step, and the AMS team will need to revisit and refine the performance measures as the project moves forward.

Substep 1.6: Select/Determine AMS Tools

Note: Outputs of this step will populate Section 6 of the analysis plan, "AMS Methodology/Tools."

Once the scenarios and strategies are identified, the AMS managers will begin to explore and select the appropriate AMS approach to be applied. This is a critical step in the AMS methodology as the selection of the appropriate approach and tool type (and ultimately the selection of a specific tool) will ensure that the analysis meets the needs of the study and will streamline the AMS process. This step follows the preliminary scoping steps because project partners must first have an understanding of the ICM strategies, scenarios and operational conditions of interest for the modeling, as well as a general grasp of the available data, as a precursor to tool selection. For example, if partners want to model pricing strategies, it will be important to select a tool that can accommodate this. Modeling of traveler diversion will require a combination of tools that can produce results that can be assimilated to build the desired understanding. This is often a multi-iteration process with the project analysts initially focused on identifying a high-level category of tool to use, then focusing on identifying key capabilities provided by different tool types, and then proceeding to select the specific tool to apply in the AMS.

Key steps in the evaluation and selection of the ICM AMS tools include:

a. Research and identify available analysis tool type(s) for the study area – In this step, the AMS manager will research and compile information on models and analysis tool type(s) currently in use in the region. This may include models that are used on a continual basis in the region (e.g., the regional travel demand model) as well as individual models that were used for specific, one-time-only analysis in or near the corridor. For each model or tool, the AMS manager should identify:

- The analysis package or tool (i.e., name and version of the software);
- The year of the analysis;
- The time periods available for analysis;
- Facilities represented in the model;
- Modes represented in the tool;
- Any special scenarios available in the model (e.g., incidents, special events, weather); and
- High-level assessment of capabilities and limitations.

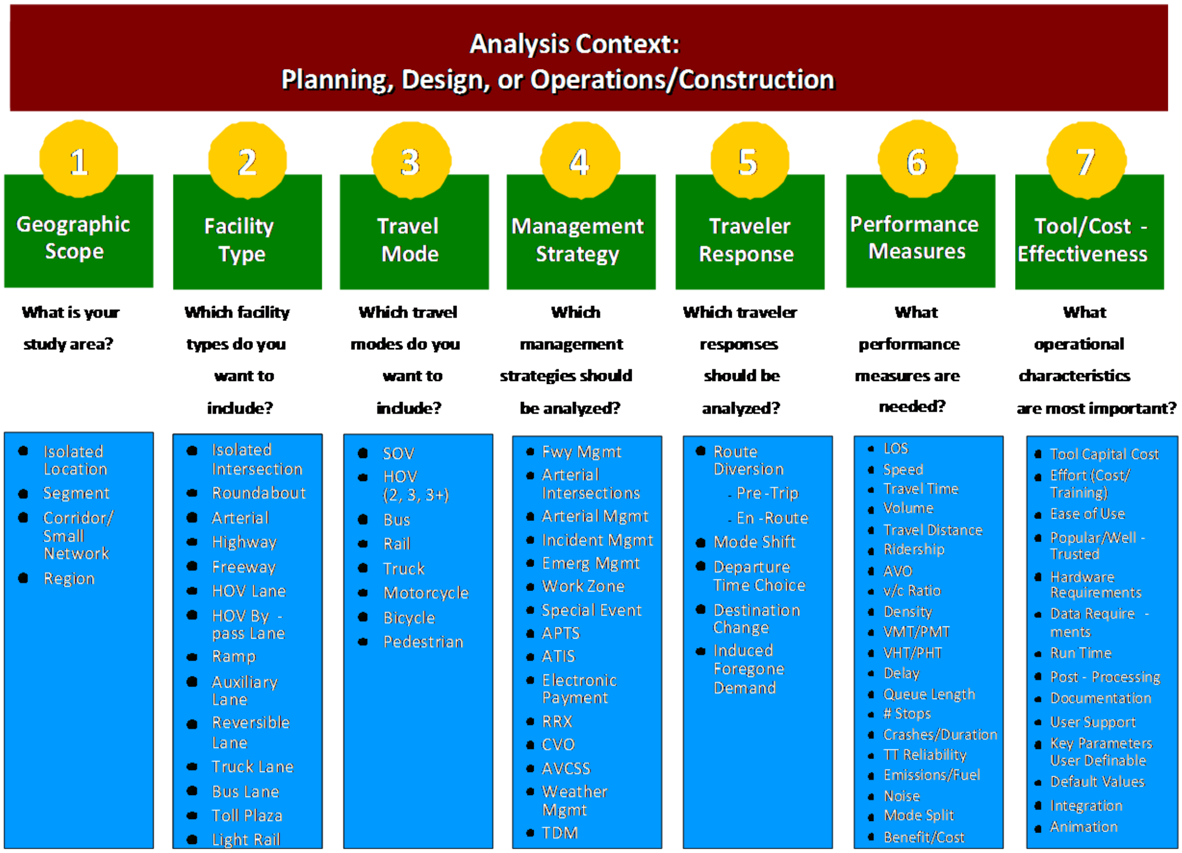
The availability of a model or tool in a region is a first step, and should not be used as the sole determinant for selecting the models and tools used in the AMS. In subsequent steps, the AMS project managers will assess their individual needs and map these to an appropriate tool or combination of integrated tools. However, this scan of available tools helps to educate project partners about the range of tools available, their relative advantages and disadvantages, and is useful in ultimately selecting the appropriate set. It is also useful in identifying potential data sources for the model development. The FHWA Traffic Analysis Toolbox is a useful reference for this step.

b. Identify factors for selecting tool type(s) – The AMS managers will identify and perform a critical analysis of the key factors that will determine the required robustness of the analysis toolset selected. The resulting analysis will also be used in a subsequent step to map project needs to an appropriate tool, or combination of tools. Initial factors will include those that the AMS managers determined in the earlier preliminary scoping activities accomplished under Substep 1.2, "Define Corridor and Existing Operational Conditions."

c. Select the Appropriate Tool Type(s) – Once the scan of available tools is complete, and the AMS team has had the chance to identify and critically analyze the selection criteria based on the project needs, the team is ready to select the tool type(s).

The FHWA Traffic Analysis Toolbox initiative includes a spreadsheet-based decision support tool that the AMS team can use to weigh various factors identified by the AMS managers, and will suggest an appropriate tool(s). The decision support tool will not recommend a specific software vendor's tool, but instead will identify an appropriate *category* of tool based on the input factors. The AMS team will still need to evaluate specific vendor products within these categories. Process documentation plus the automated tool are available at: http://ops.fhwa.dot.gov/Travel/Traffic_Analysis_Tools/traffic_analysis_tools.htm. Figure 3-3 provides an overview of the basic factors the FHWA Traffic Analysis Toolbox method considers.

Figure 3-3. FHWA Traffic Analysis Toolbox: Overview of Analysis Factors to Be Considered in Selecting Appropriate AMS Tools*



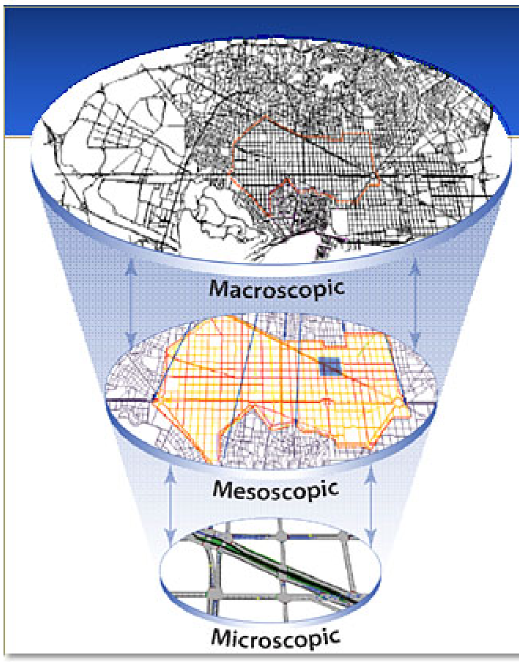
[Source: FHWA Traffic Analysis Toolbox Volume II Decision Support Methodology for Selecting Traffic Analysis Tools.]

The tasks completed in the development of the analysis plan to this point should provide most of the inputs necessary to complete categories one through six in the FHWA Traffic Analysis Toolbox Decision Support Methodology, as shown in Figure 3-3. Particular care should go into assessing the seventh category on Tool/Cost Effectiveness. Assessing this final factor will consist of evaluating the cost-performance tradeoffs associated with qualifying tool options that satisfy the first six criteria. Once a qualifying set of candidate tools have been identified, AMS managers can focus on which tools can deliver the greatest value for the overall estimated cost both in software and configuration/calibration load. This will be influenced in part by the general understanding of available data (and workload required to render that data useful for modeling effort, which may vary by tool in light of their various capabilities), staff skills, previous modeling efforts that can potentially be leveraged for this effort, etc.

In assessing the needs of ICM project analysis, it is very possible that multiple tools will need to be utilized. A single tool may not be sufficiently robust to handle the analysis needs, and the AMS managers may need to consider integrating the analysis capabilities from multiple tools to achieve the necessary abilities. For example, the integration of multiple tools was the analysis approach eventually selected by all three ICM Pioneer Sites (Dallas, Minneapolis, and San Diego). In this step the analysis team will also specify requirements for interfacing between different tools.

Once appropriate tool categories have been selected, the AMS manager can use the documentation provided with the FHWA Traffic Analysis Toolbox Volume III to research the range and capabilities of individual software packages and tools within the selected category. Figure 3-4 depicts the tools selected by each of the ICM AMS Pioneer Sites.

Figure 3-4. ICM AMS Pioneer Site Modeling Tools Used



	Minneapolis Minnesota	Dallas Texas	San Diego California
Macroscopic	Metro Model in TP+	North Central Texas Council of Governments Model (TransCAD)	TransCAD
Mesoscopic	Dynus T – supported by University of Arizona	DIRECT – supported by Southern Methodist University (SMU)	
Microscopic			TransModeler Micro

[Source: Cambridge Systematics, June 2004.]

One of the distinguishing characteristics of the ICM AMS Methodology is the blending of strengths from multiple tools, to capture corridor-wide system dynamics and produce the depth of insight necessary to make informed ICM-related decisions.

The USDOT documentation includes web links to individual research organizations and vendors supporting the various packages for even more information. Certainly, peer research can be valuable as well. From this research, the AMS team can make a high-confidence decision regarding the specific tool, or combination of tools, that will best meet the requirements of the AMS project's needs.

Substep 1.7: Provide Summary of Analysis Settings

Note: Output of this substep will populate Section 7 of the analysis plan, "Summary of Analysis Settings."

In this step, AMS managers will develop and define the specific settings that summarize the specific agreements stakeholders have arrived at regarding the methods and assumptions that will be used in the modeling approach.

The settings include the basic information (e.g., year of analysis, time periods, etc.) plus information on the characteristics of an incident to be modeled. These settings represent preliminary guidance to the modelers. At this stage, they are informed general assumptions based upon stakeholder assumptions regarding likely future conditions. As the analysis moves forward, these assumptions will be validated with additional data. Table 3-3 provides an example snapshot of the summary analysis settings defined for the I-15 Corridor in San Diego.

Table 3-3. Example Summary of Analysis Settings

Parameter	Value	Guidance
Base year	2003	The SANDAG regional travel demand model was last validated for year 2003, and during 2003 there was no major construction activity within the corridor.
Analysis year	2012	The analysis year is derived from the anticipated completion of construction of the I-15 system, and the implementation of ICM strategies.
Time period of analysis	AM	The AM peak period has the most concentrated traffic congestion.
Simulation period	3-5 hrs	6 AM – 9 AM is the primary analysis period. Future baseline scenarios run through 6 AM – 11 AM to allow for congestion to build and dissipate.
Freeway incident location	South of Ted Williams Pkwy	This location experiences a high number of incidents, offers the potential for route diversion, and has a high impact on corridor travel.
Freeway incident duration	45 minutes	This duration is chosen to represent a major blockage in the peak period based on analysis of actual incident records. Incident occurs at 7 AM and is cleared by 7:45 AM.
Freeway incident severity	Lane closures	3 lanes closed and reduced speeds on lanes 4 and 5 from 7 AM to 7:30 AM. Only 2 lanes closed for the remaining duration of the incident and reduced speeds on lanes 3, 4, and 5.
Arterial incident location	On Carmel Mountain Rd east of I-15	Based on 2012 demand projections to calculate incident rates for different arterials under study.
Arterial incident duration	40 minutes	This duration is chosen to represent a major blockage in the peak period. Incident occurs at 7:30 AM and is cleared by 8:10 AM.
Arterial incident severity	Lane closures	Variable lane closures and speed reduction.

[Source: San Diego ICM Stage 2 AMS Analysis Plan, 2010.]

Table 3-4 summarizes expanded model settings regarding scenario inputs and assumptions used in the San Diego I-15 Corridor Pioneer Site, which were used in the specific analysis of ICM strategies. Importantly, these expanded settings display the anticipated model settings for both pre-ICM (without the ICM capabilities in place) and post-ICM (with the ICM capabilities after deployment) hypotheses. These model settings are based on an understanding of how the ICM strategies will be implemented along with data on the observed impacts of similar strategies in other regions. Again, these initial settings represent informed general assumptions based upon the knowledge of agency's staff of likely future conditions and ICM impacts. As the analysis moves forward, these assumptions will need to be validated with traffic data and before-after evaluation of traveler surveys.

> *"Obtaining this level of detail is very difficult. Operators will typically first express that with ICM they expect earlier dissemination of traveler information. But the modeler will need to know 'What do you mean by faster dissemination? What specifically are you disseminating and how much faster?'"*
>
> Karl Wunderlich, Noblis

Table 3-3. San Diego I 15 Corridor Model Assumptions/Inputs

Outcome of Strategies		Summary/Notes to Modeling Team	Without ICM	With ICM in Place
1.	**En-Route Information**			
1.1	Earlier dissemination of en-route incident and travel time information	Because of quicker notification, en-route traveler information systems will disseminate incident information earlier to travelers. The effect will be that more travelers will be able to alter routes, modes, and departure times. Incident duration stays the same with and without ICM.	10 minutes to dissemination. 5% of travelers were assumed to have traveler information.	• 2 minutes to dissemination; and • 30% of travelers (smart phones, 511, radio combined) with traveler information. In the baseline year of 2003,
1.2	Comparative travel times (mode and route)	Information dissemination (pre-trip and en-route) will include travel time comparisons for freeway, general purpose lanes, arterial, and transit. The effect will be that more travelers will choose the best options to maintain consistent trip times.	General purpose lane and mainline travel time	Travelers will make diversion choices at equal intervals of time (for the next time period). The decision choice is based on a generalized cost that feeds into a decision model. The effect will be that as conditions worsen, more travelers will take more alternative options including transit.
2.	**Improved Traffic Management**			
2.1	Incident signal retiming plans	"Flush" signal timing plans that are coordinated and allow progression through different jurisdictions. The effect will be reduced arterial travel times during incidents or special event situations.	30 minutes to implement	• Based on location as specified in "Caltrans Primer" on Signal Coordination; • 10 minutes to implement (variable based on severity); • Higher throughput; and • Off-ramp and diversion planning.
2.2	Freeway ramp metering and signal coordination	Incident location-based strategy to coordinate arterial traffic signals with ramp meters.	None	Coordination under integrated ramp metering framework.
2.3	HOT lanes	Existing today, HOT lanes are included in the modeling. Can be opened to all traffic during major incidents. Option of adding additional lane in incident direction using movable barrier.	Maintain HOT lanes during major incidents	Open HOT lanes to all traffic during major incidents to maximize throughput (I-15 managed lanes operations and traffic incident management plans).
3.	**Improved Transit Management**			
3.1	Reduced time of detection, notification, and verification of incidents	Currently, incident management is handled by Caltrans and other responders. The system will be streamlined to provide coordination of major traffic incidents between TMC/Caltrans and FasTrak CSC/SANDAG. Clear-cut procedures and understanding of decisionmaking process and delegation of authority/responsibility of actions will reduce response times.	All agencies notified within 30-60 min. Incident clearance in less than 90 minutes.	All agencies notified within 5 minutes. I-15 managed lanes and traffic incident management plans provide a blue print for coordination.

[Source: San Diego I-15 Stage 2 ICM AMS Analysis Plan, 2010.]

Substep 1.8: Describe the AMS Approach

Note: Outcomes from the completion of this step will populate Section 8 of the analysis plan, "Summary of the AMS Approach."

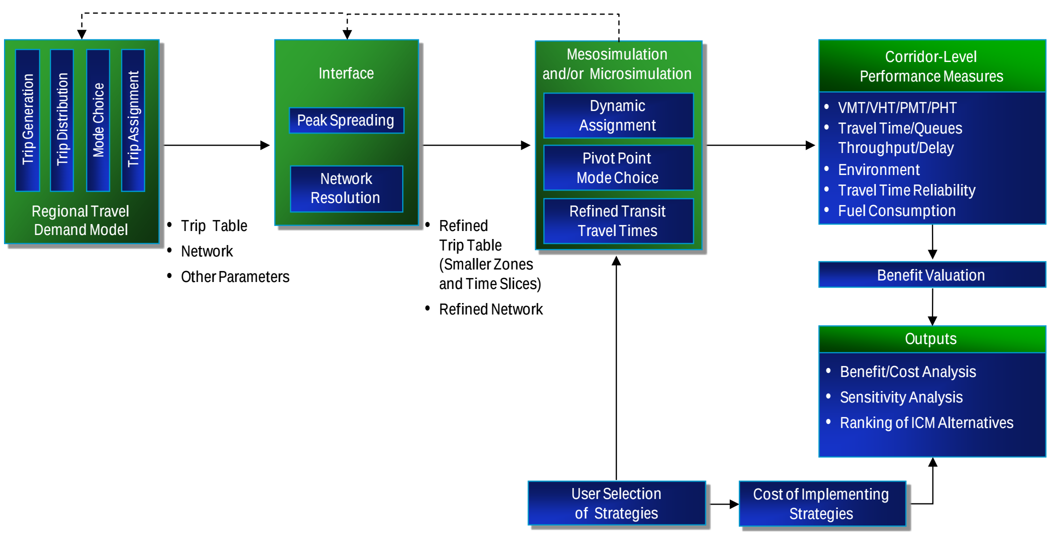
In this step, the AMS team will summarize the planned approach that will be used to conduct the AMS and develop and document the specific approach it will use to calibrate the models used for the AMS effort. This section of the analysis plan should minimally include identification of:

- Modeling package(s) /tools to be used;
- Baseline networks and years;
- Analysis periods (i.e., time-of-day); and
- Future forecast networks and years.

Practitioners developing the analysis methodology and approach often find that a graphical depiction of the modeling process, showing major analysis steps and links/interfaces between the analysis modules is useful in documenting this approach and communicating it to stakeholders. This is particularly important for complex modeling approaches or those approaches combining the capabilities of multiple model packages.

Figure 3-5 presents an example flow chart of the approach used in the Test Corridor AMS. This approach is presented only as an example framework, and different agencies may develop variations based on their individual needs and requirements. First, regional travel demand modeling would be conducted, then network and demand data would be exported to micro- and mesosimulation models along with specific ICM interface inputs (such as peak spreading assumptions and network resolution information). The simulation models would process dynamic assignment, assisted by a pivot point mode choice model and using refined transit travel times. The results of these model runs could then be compared against the defined output performance measures of interest to this corridor. Coupling these results with the estimated costs associated with the ICM strategies of choice for this corridor, the AMS team could then perform cost-benefit valuation analysis to support benefit-cost analysis, sensitivity (or "what if") analysis and rankings of ICM alternatives.

Figure 3-5. Example AMS Process (Used for Test Corridor AMS)



[Source: Cambridge Systematics, June 2004.]

Substep 1.9: Summarize Guidance for Model Calibration

Note: Output from the completion of this step will populate Section 9 of the analysis plan, "Guidance for Model Calibration."

Model calibration is one of the most critical steps in AMS; therefore, it is important to plan and document the process that will be used for calibration early in the AMS effort. Model calibration refers to the ability of the models to successfully re-create observed conditions. A key objective in this substep is a clear and mutual understanding between the AMS managers, stakeholders, and the technical modeling team of the process and criteria that will be used to calibrate the models. This shared understanding is a crucial element (along with an understanding of the quality of the data and key modeling assumptions) on which the credibility of the eventual AMS results depends.

USDOT provides valuable guidance in developing and implementing this calibration methodology as part of the Traffic Analysis Tools initiative.[9]

See Workstep 3, "Model Setup and Calibration," for examples of model criteria used by the ICM Pioneer Sites.

Substep 1.10: Develop budget, timeframe, and roles

Note: Output from the completion of this workstep will populate Sections 10-12 of the analysis plan, "Budget/Resources," "Timeline," and "Key Project Roles."

In this step, AMS roles will be defined and clarified among the various project stakeholders. Table 3-5 provides a high-level example of how key project roles can be displayed. The project team will also want to include a summary of the estimated budget and timeframe in the AMS Plan. These will be updated regularly as the AMS effort moves forward.

Table 3-4. Example High-Level Allocation of Responsibilities

Workstep	AMS Project Manager	Operations Manager	Planning Manager	Modelers	Systems Manager	Stakeholders
Develop Analysis Plan	●	0	0	0	0	0
Develop Data Collection Plan and Collect Data	●	0	0	0	0	0
Model Setup and Calibration	●	0	–	●	–	–
Alternatives Analysis and Documentation	●	0	0	●	0	–
Continuous Improvement	●	●	●	●	●	0

● Primary responsibility.
0 Secondary responsibility.

[9] Documentation and guidance are available at: http://ops.fhwa.dot.gov/travel/traffic_analysis_tools/traffic_analysis_tools.htm.

Output

The outputs of this workstep include:

- Project and initiative-level kickoff meeting presentations and materials (plus participation and facilitation of these meetings);
- MOU/MOA among initiative stakeholder organizations documenting project scope and anticipated roles and levels of effort; and
- Draft and final analysis plan.

Although the analysis plan is designated as a single deliverable, there may be multiple sub-deliverables (e.g., technical memos, presentations, etc.) that are generated in the development of this plan, depending on workflow and individuals responsible for compiling the necessary information. The analysis plan is expected to undergo at least three major revisions prior to finalization to allow for additional levels of detail as the process moves forward and to allow for stakeholder input and comment.

Timeframe

The time necessary to develop the analysis plan is variable depending on the familiarity of the AMS managers with the corridor and planned ICM strategies, availability of documentation, quality of the ICM CONOPS, timeline of the ICM deployment, and willingness of local experts to coordinate with the AMS team. Typical development of the analysis plan would be expected to last anywhere from approximately 4 to 12 months.

The development of the analysis plan usually begins in the early stages of the ICM planning effort, often in parallel with the development of the CONOPS and requirements. However, it is critical that the analysis plan not be completed until the full definitions of the anticipated ICM strategies are finalized; the strategies to be analyzed must be known prior to the finalization of the analysis plan. Often, the analysis plan continues as a "living document" throughout the analysis lifecycle, constantly being updated as new information is learned as steps proceed. In this role, it also serves as documentation of changes made throughout the analysis.

Challenges

Some of the major challenges observed in developing the analysis plan are listed below.

- ICM strategies often represent new approaches to traffic management in many regions. Unfamiliarity with the strategies may make it more difficult to formulate an analysis approach and identify the likely impacts of the proposed systems. The AMS approach is designed to promote a flexible analysis methodology so that the approach can be continually improved as more information is gained and lessons are learned. However, it is important that deploying agencies define and refine their proposed ICM strategies prior to the completion of the analysis plan so that the AMS approach is appropriate to the final ICM plans.
- The evaluation of ICM strategies may require the use of unfamiliar performance measures, particularly those specifically focused on nonrecurring congestion impacts. In other cases existing performance measures may not be specific enough to provide for meaningful ICM analysis. Therefore, some additional education may be necessary on the part of AMS managers to inform stakeholders on the importance of these new performance measures.

- Analysis of "average day" conditions as performed for many typical planning efforts is not sufficient for analysis of ICM deployments. Many ICM strategies are specifically targeted at mitigating non-typical events (e.g., high travel demand, incidents, inclement weather). Therefore, the analysis must be expanded beyond the "typical day" to properly measure the potential benefits of ICM.
- The USDOT has provided useful guidance on selecting appropriate analysis tools as part of the Traffic Analysis Tools initiative. However, this guidance is intended to steer practitioners to the appropriate general category of analysis tool and model packages, not to specific software vendors. AMS managers should carefully investigate the capabilities of options within the selected category to identify the most appropriate tools and models. In conducting this assessment, AMS managers should seek out guidance from peers who may have conducted similar analysis or used some of the tools under consideration. Further, when selecting and evaluating software, practitioners should keep in mind that software vendors are continuously updating their packages to meet unmet needs and identified deficiencies. What was the best last year may not be as productive this year. Particularly when dealing with ICM, many new advances are in-process, so it is helpful to contact vendors to obtain the latest information.

Resources

Program managers can expect to allocate approximately 20-30% of the project budget to this step of the initiative. This investment pays dividends in accurately scoping and shaping the AMS effort to achieve the desired objectives, including design of the AMS approach to support longer term analysis of ICM strategies and corridor performance as the corridor and its needs change. This investment can also support enhanced transportation planning, real-time decision support capabilities, and analysis needs of other related initiatives (i.e., ATDM, etc.).

This workstep will require the involvement of the full suite of representative stakeholders in ICM from State, regional, and local transportation and planning agencies across the full range of roles, including freeway, arterial, and transit program and technical managers, engineers, and analysts; transportation planners; and technical modeling and simulation experts.

3.2 Workstep 2: Develop a Data Collection Plan and Collect Data

Objective and Value

The analysis plan identified high-level data requirements and datasets to be assembled, along with stakeholders responsible for collecting the data. In this step, a more detailed data collection plan will be formulated to guide the compilation of the necessary data. The objective of this workstep is to build on the data requirements outlined in the analysis plan to develop a detailed data collection plan. The data collection plan will guide the compilation, analysis, and archiving of data that will be required to support the actual conduct of the AMS.

The value of successfully completing this workstep will be the compilation of relevant and useful datasets and metadata necessary to develop the enhanced models and analysis to be utilized in the subsequent steps, and to provide the foundation for continuous process improvement. The data collection plan will help to ensure that the data collected is of sufficient quality for the needs of the study and will guide the partners in collecting the data using methods that minimize the expenditure of resources on this task.

Key Mechanisms:

- Data Collection Plan Kickoff Meeting
- Research and Data Gathering using Templates
- Field Reviews
- Individual Interviews

Approach and Substeps

Figure 3-6 presents an overview of the substeps related to the development and implementation of the Data Collection Plan. The output from these substeps maps directly to completion of the Data Collection Plan (See Table 3-6, Example Outline for Data Collection Plan). Subsequent discussions provide additional detail on the recommended conduct of the identified subtasks.

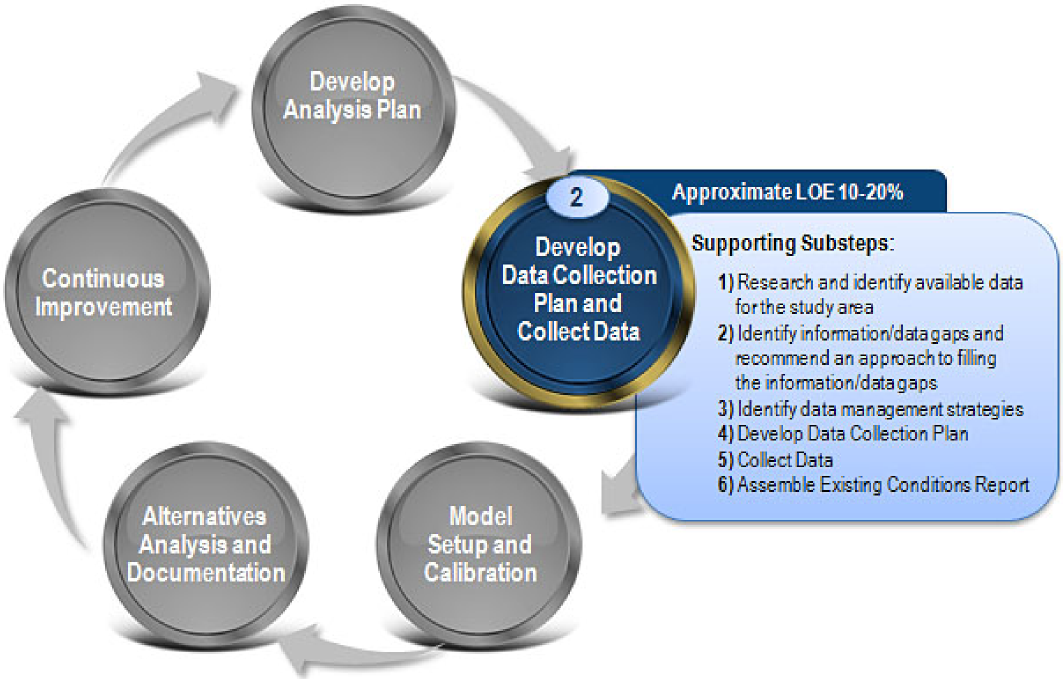
The earlier scoping work for the analysis plan can be used to complete Section 1 of the data collection plan ("Introduction and Background"). Similar to the development of the analysis plan, it is likely that in the course of investigating and collecting the data, opportunities and challenges will be encountered that result in modifications to the data requirements and data collection plan. The data collection plan should remain sufficiently flexible so that lessons learned in the compilation of data sources may be adapted and incorporated as part of the continuous improvement of the AMS effort.

Table 3-5. Example Outline for Data Collection Plan

Example Data Collection Plan Outline

1. Introduction and Background
2. Data Collection Methodology
3. Documentation Review
4. Summary of Input Data for AMS
5. Summary of Data Requirements for Approaches and Strategies
6. Current State of Required Data and Gap Identification
    - *6.1 Arterial-Related Data*
    - *6.2 Freeway-Related Data*
    - *6.3 Transit-Related Data*
7. Summary of Data Collection Methods

Figure 3-6 Overview of Workstep 2: Develop Data Collection Plan and Collect Data



[Source: Research and Innovative Technology Administration and Cambridge Systematics.]

Specific substeps in the development of the “Data Collection Plan and Collect Data” workstep include:

Substep 2.1: Research Available Data

Data sources and data requirements identified in the analysis plan should be used to identify available data for the corridor. Table 3-7 shows an example of an at-a-glance high-level summary of the preliminary types of data anticipated to be required for the AMS. The analysis plan should also identify those individuals/ stakeholders responsible for compiling the data. The AMS managers should work closely with stakeholders in compiling the data. A significant challenge in collecting useful AMS data is that the data is often required to be concurrent (i.e., all collected for the same period of time, not assembled from data collected on various dates and times) across all facilities and modes to be useful. If possible, the AMS managers should obtain samples of the datasets prior to full collection to view the content and format of the data and adjust collection plans if necessary.

Table 3-6. Example Data Requirements for AMS

Network	Travel Demand	Traffic Control	Transit	ITS Elements
Link distances	Link Volume	Freeways	Transit Routes	Surveillance System
Free-flow speeds	Traffic Composition	Ramp Metering	Transit Stops	Detector Type
Geometrics – freeways	On- and Off-Ramp Volumes	Type (local, system-wide)	Location	Detector Spacing
# Travel Lanes	Turning Movement Counts	Detectors	Geometrics	CCTV
Presence of shoulders	Vehicle Trip Tables	Metering Rates	Dwell Times	Information Dissemination
# HOV lanes (if any)	Person Trip Tables	Algorithms (adaptive metering)	Transit Schedules	CMS
Operation of HOV lanes	Transit Ridership	Mainline Control	Schedule Adherence Data	HAR
Accel/Dec lanes		Metering	Transfer Locations	Other (e.g., 511)
Grade		Lane Use Signals	Transit Speeds	In-vehicle Systems
Curvature		Variable Speed Limits	Transit Fares	Incident Management
Ramps		Arterials	Payment Mechanisms	Incident Detection
Geometrics – arterials		Signal System Description	Paratransit	CAD System
Number of lanes		Controller Type	Demand-responsive	Response and Clearance
Lane usage		Phasing	Rideshare programs	Incident Data Logs
Length of turn pockets		Detector Type and Placement		Tolling System
Grade		Signal Settings		Type
Turning restrictions		Signal Timing Plans		Pricing Mechanisms
Parking		Transit Signal Priority System		TMC
Parking facilities		Control Logic		Control Software/Functions
Location		Detection		Communications
Capacity		Settings		Data Archival Dissemination
Park-and-ride lots		Emergency Preemption System		Transit/Fleet Management System
Location		Control Logic		AVL
Capacity		Detection		Communications
		Settings		Traveler Information Bus Stops

NOTES:

- These data must be provided for all links in the corridor study area.
- These data must be provided for a consistent analysis time period, including the same date for data from all facilities in the corridor area.
- To facilitate the assessment of variability in traffic volumes and speeds, data must be provided for multiple days of the week and months of the year for all facilities in the study corridor.

[Source: Cambridge Systematics – Data Collection List to ICM Pioneer Sites.]

Substep 2.2: Identify Information/Data Gaps

Once available data sources have been investigated and dataset samples reviewed, the AMS managers should assess the appropriateness of the available data relative to the analysis needs to identify any critical gaps in data availability. Potential approaches to filling data gaps should be investigated, and recommended approaches should be documented in the data collection plan.

Substep 2.3: Identify Data Management Strategies

In this step, procedures for conducting data quality control and data archiving should be identified. Any required thresholds for minimal data quality should be identified as should high-level descriptions of processes for addressing data shortcomings. Plans for archiving the data should also be identified. Responsibilities for data quality testing and data archiving should be clearly defined. Determining the acceptable quality thresholds for the various types of data to be used in the AMS, from the perspective the various stakeholders, is a crucial dependency for the credibility of the eventual results. The various data may not all share the same quality thresholds. Gaps in data and higher latency, for example, may be acceptable for some data types and not others. The AMS managers should place sufficient emphasis on this step, via a dedicated data review meeting or other mechanism, to ensure they obtain stakeholder concurrence on acceptable quality standards for the data and establish data management strategies.

Further, planning will need to occur for the physical computational assets necessary to store and manage large quantities of data. Large amounts of detector data, for example, require hard disk sizes and data processing software that are not always standard equipment in all agencies or consultancies.

Substep 2.4: Develop Data Collection Plan

The data collection plan should document all of the **above** information and detail data elements to be obtained and their respective data sources. The data collection plan should also recommend data collection methodologies and develop budget and timeframe estimates to fill data gaps. See the Pioneer Site data collection plans for examples (Appendix B of this document provides an example data collection plan developed for the San Diego I-15 Pioneer Corridor).

Substep 2.5: Collect Data

> *"Investing a relatively small amount of effort in this early phase to maintain good records on a site's data can shave half of the cost of future efforts."*
>
> Vassili Alexiadis, Program Manager for the Pioneer Site AMS Initiative, Cambridge Systematics, Inc.

Once the data collection plan is developed, the required data should be collected. This data collection should include the compilation of available data as well as the implementation of identified approaches for filling any data gaps. Many times, the data collection process starts in parallel with the development of the data collection plan. This allows sample datasets to be reviewed and any data discrepancies anticipated and addressed in the plan. Data collection activities should also utilize the data quality and data archiving procedures documented in the data collection plan. Tasks involved in this activity include:

a. Assemble/collect physical infrastructure, geometrics, and transit service routes – much of this data is likely to be available in existing models and regional Geographic Information Systems (GIS). Other data may utilize other data sources or require manual data collection, as defined in the data collection plan

b. Assemble/collect existing transportation performance data for all modes within the study corridor including, but not limited to:

- Peak-period traffic volumes on the freeway and parallel arterials;

- Vehicle occupancies;
- Truck percentages;
- Transit ridership;
- Traffic control data (e.g., arterial traffic signal and ramp meter timings and phasings)
- Congestion data; delay data;
- Identification of known corridor bottlenecks
- Travel time data; speed data; and
- Accident and incident data.

c. Gather Available Information from Corridor Studies.

These studies include those currently underway, as well as those that have been recently completed. Example studies include, but not limited to: existing conditions analyses; environmental impact studies, and lists of projects and strategies that have been planned or programmed.

d. Conduct Field reviews of all travel modes within the study corridor. Field reviews provide the AMS team with a better understanding of existing travel conditions and problems. Top priorities for site visits include any known bottleneck locations, multimodal transfer points (e.g., park and ride lots or major transit stations), major interchanges or locations that serve as decision points for travelers, and control centers/facilities for the corridor operations of the various modes (e.g., traffic management centers or transit control centers).

Substep 2.6: Assemble Existing Conditions Report

All data collected in this effort should be analyzed and archived according to the data management procedures documented in the data collection plan. Any identified problems with data quality or the successful archiving of data should be immediately communicated to the AMS managers as part of the continual improvement process. The collected data should be documented in an existing conditions report. The existing conditions report is a key element in problem diagnosis and solution/alternatives design. The existing conditions report is critical not only to AMS but to ICM strategy design, ICM alternatives formulation, discussions with ICM stakeholders, performance measure design, and, ultimately, the choice of preferred strategies. This report should provide:

> **TIP:** Take pictures and video of the corridor during site visits to support a visual understanding of the corridor by stakeholders.

- Summaries of the data collected;
- Outcomes of all data quality reviews and any consistency/reasonableness checks as defined in the data collection plan;
- Statement of acceptance/rejection of the individual data sets; and
- Identification of any key problem areas along with an explanation of cause and identification of risk to the AMS.

The findings in the existing conditions report should be presented and discussed at a meeting with all key stakeholders.

Substep 2.7: Maintain Datasets

It is critically important that the datasets be archived and maintained, along with all data dictionaries and supporting information, according to the data maintenance plans defined in the Data Collection Plan. Investing in maintaining the datasets will save valuable resources in subsequent tasks as well as future analysis efforts. Failure to properly maintain the datasets can result in a significant loss of investment in the data collection task and in a reduction in data fidelity. Also it is worth implementing software version control to ensure ease of moving between time-stamped versions of networks, scenario datasets, etc.

Output

The outputs of this workstep include:

- Draft and final data collection plan;
- Existing conditions report; and
- Archived data sets.

Timeframe

The timeframe required to complete this workstep is dependent on the types, quantity, and quality of data required, the data collection methods, and the amount of readily available archived data from automated sources. Often times, the data collection process starts in parallel with the development of the actual data collection plan. The timeframe for developing the data collection plan is estimated to be approximately 2 to 4 months. Completing the collection of data is extremely variable and may take an additional 2 to 6 months depending on the data required.

Challenges

Due to the innovative nature of many ICM strategies, the collection of relevant data to support AMS offers several unique challenges:

- The focus on many ICM strategies on nonrecurring congestion may require the development of datasets focused on travel-time reliability and factors influencing nonrecurring congestion (e.g., incident occurrence or weather conditions). Automated data sources are often best for collecting the long-term data necessary to assess these nonrecurring performance measures; however, many existing automated data collection systems may lack the robustness or reliability to effectively compile relevant data sets. A thorough assessment of the data quality from all sources is recommended to identify any potential problems early on in the process and establish methods to address any deficiencies.
- Performance measures necessary for the AMS may require the collection of datasets that are unfamiliar to the managing agency. The AMS manager should seek out peer information on collecting this data for all new or unfamiliar data requirements.
- Data for AMS is required to be collected concurrently – collected for the same dates and times across all modes and facilities. This is often different from typical planning data collection efforts that are assembled from data compiled from different dates and times. The

demands for concurrent data can require additional effort to coordinate and synchronize the multiple data collection efforts.

- Data quality from automated data sources (e.g., roadway loop detectors) may sometimes be insufficient for modeling purposes. Sample datasets should be obtained early in the data collection process and analyzed to assess data quality. The data collection plan should specify data quality procedures and minimal data quality requirements for this purpose. Further, AMS managers should discuss any data quality issues with operations personnel familiar with the data source during the development of the data collection plan in order to understand and anticipate any problems with data source reliability, data accuracy or other condition specific issues (e.g., inaccurate speeds recorded during high volume periods).

- Due to the emerging nature of many ICM strategies and the currently limited data on traveler behaviors in response to the strategy implementation, the AMS Team may need to exercise engineering judgment in the identification of likely impacts (e.g., likely route diversion rates) to be implemented in the analysis. For these variables and parameters for impacts with limited data points that may be used from previous deployments, the AMS team may want to flag these and consider conducting sensitivity analysis to account for misjudgment of the variables.

- It is critical the datasets be archived and maintained, along with all data dictionaries and supporting information, according to the data maintenance plans defined in the data collection plan. Failure to do so can result in a loss of data and the loss of resource investment in the data collection task.

Resources

Program managers can expect to allocate approximately 10-20 percent of the project budget to data collection. This investment pays dividends by creating or updating the corridor's inventory of available data which provides a foundation for continual process improvement. This workstep may take more or less time based on the state and availability of relevant data within the corridor. This workstep will require the involvement of the full suite of representative stakeholders in ICM from State, regional, and local transportation and planning agencies across the full range of roles, including freeway, arterial, and transit program and technical managers, engineers, and analysts; transportation planners; and technical modeling and simulation experts.

3.3 Workstep 3: Model Setup and Calibration

Objective and Value

The objective for this workstep is to develop the models and analysis methods to be used in the evaluation. This includes the development of the baseline models and the calibration of the models to ensure the accurate representation of travel conditions in the analysis. The calibration and validation efforts are required to make sure that the base models are well calibrated and validated so that the errors don't get carried forward in the process This step is absolutely critical to the overall success of the AMS.

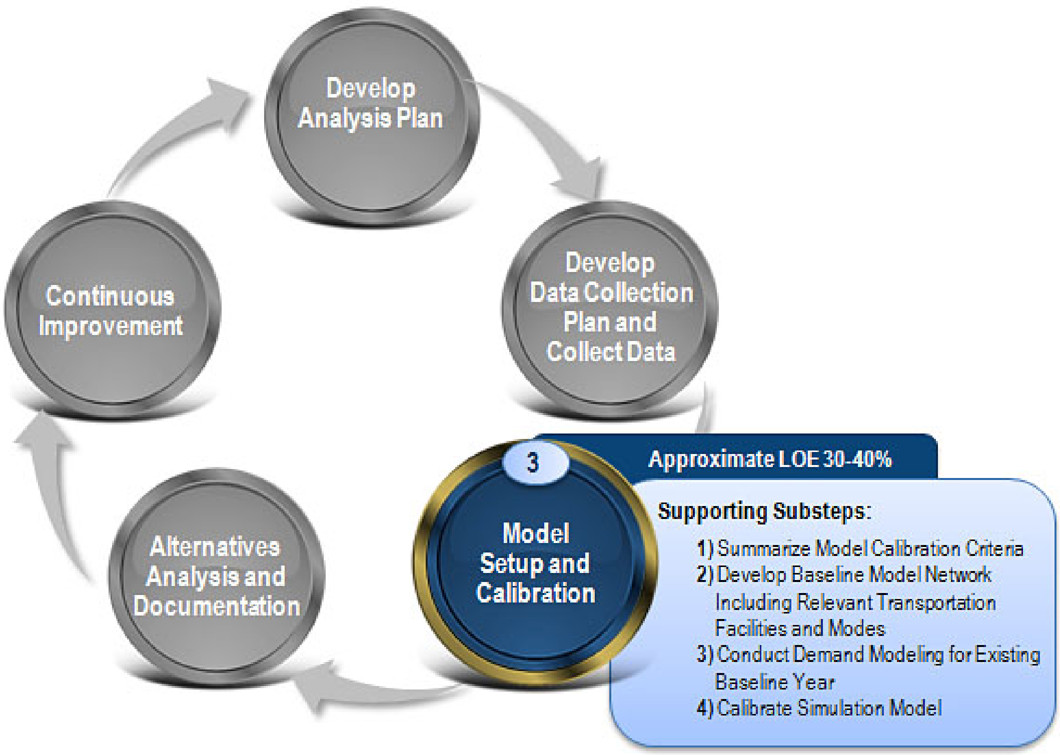
The development and calibration of the models is often the most time- and resource- consuming task to be completed in the AMS. It can also be the riskiest as failure to suitably invest resources in this task can result in models that are incapable of providing the correct assessment of ICM impacts, thus, requiring that this workstep be repeated. The AMS manager and team should assure this workstep receives sufficient emphasis.

Done correctly, this workstep will result in a model with the appropriate robustness and analysis capability to support the analysis in subsequent worksteps, and will assure the results are perceived as critical by stakeholders who observed the care with which this workstep was accomplished.

Approach and Substeps

Figure 3-7 presents an overview of the substeps related to model setup and calibration workstep for the ICM AMS effort. The USDOT has several resources that can provide more specific guidance regarding model calibration in general, including Volume III of the FHWA Traffic Analysis Toolbox.

Figure 3-7. Overview of Workstep 3: Model Setup and Calibration



[Source: Research and Innovative Technology Administration and Cambridge Systematics.]

The substeps associated with the model setup and calibration workstep are described in more detail below.

Substep 3.1: Summarize Model Calibration Criteria

Calibration criteria should be identified and the selected thresholds documented to establish the benchmarks to be achieved through the process. Documentation provided as part of the FHWA Traffic Analysis Toolbox initiative is useful in establishing these criteria.[10] Table 3-8 illustrates examples of some of the guideline model calibration criteria established for recurrent congestion used for the ICM Pioneer Sites.

[10] For more information on calibration criteria, see: FHWA *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software, 2004*.

Table 3-7. Example Guideline Calibration Criteria for Recurrent Congestion

Calibration Criteria and Measures	Calibration Acceptance Targets
• Traffic flows within 15% of observed volumes for links with peak-period volumes greater than 2,000 vph	• For 85% of cases for links with peak-period volumes greater than 2,000 vph
• Sum of all link flows	• Within 5% of sum of all link counts
• Travel times within 15%	• >85% of cases
• Visual Audits – Individual Link Speeds: Visually Acceptable Speed-Flow Relationship	• To analyst's satisfaction[11]
• Visual Audits – Bottlenecks: Visually Acceptable Queuing	• To analyst's satisfaction

For incidents, or nonrecurring congestion, the following example guideline model calibration criteria were developed as part of the ICM AMS effort:

- **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.
- **Diversion flows.** Increase in ramp volumes where diversion is expected to take place.
- **Arterial breakdown when incident.** Cycle failures or lack of cycle failures.

Table 3-9 presents a snapshot of the guideline transit-related calibration criteria used for the U.S. 75 ICM analysis for the Dallas Pioneer Site corridor.

Table 3-8. Snapshot of Guideline Transit Model Validation and Calibration Criteria for U.S. 75 ICM – Dallas

Validation Criteria and Measures	Acceptance Targets
Light-rail station volumes within 20% of observed volumes	For 85% of cases
Light-rail park-and-ride lots	
Parked cars in each lot	Within 30%
Total parked cars for all lots combined	Within 20%

[Source: Dallas U.S. 75 ICM AMS Analysis Plan, 2009.]

Substep 3.2: Develop Baseline Model Network Including Relevant Transportation Facilities and Modes

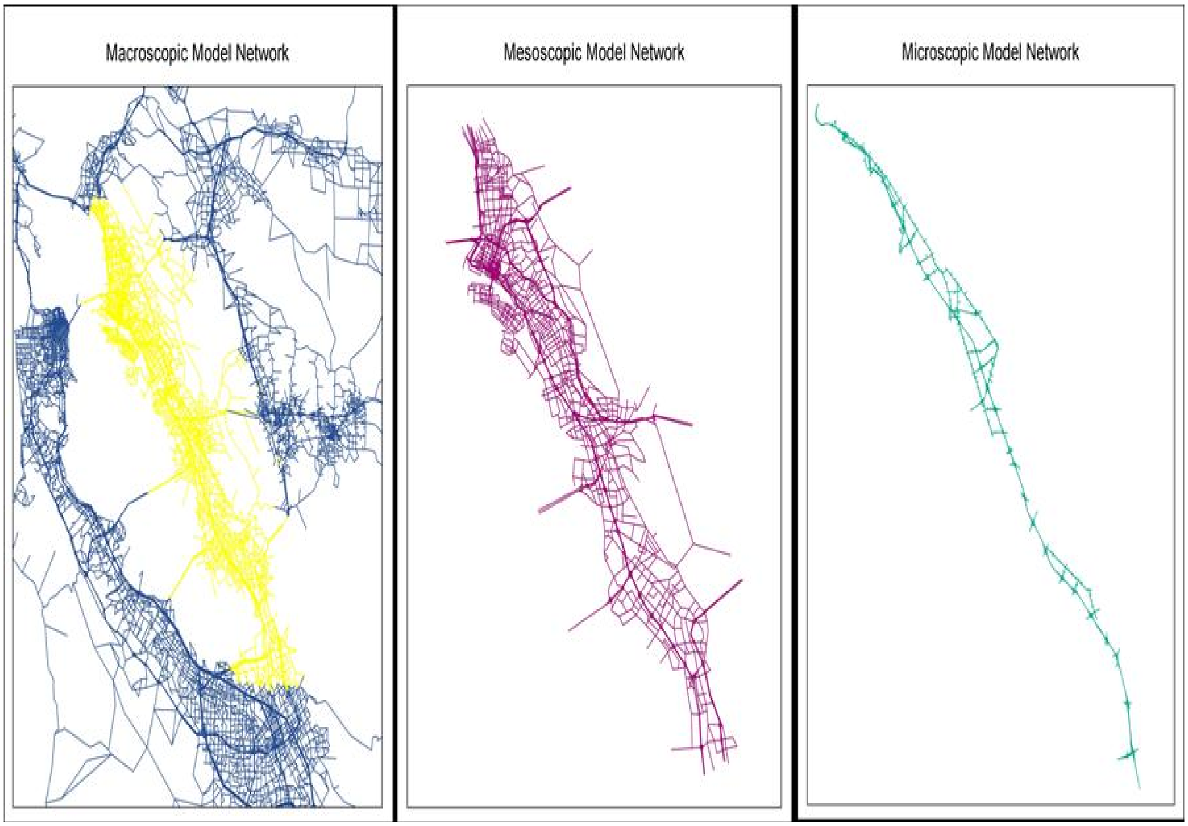
The development and refinement of the AMS process at the Pioneer Site locations revealed limitations in using currently available models for conducting assessment of ICM. As discussed previously, different tool types have different advantages and limitations. Sites may find that no single model currently available provides all the needed visibility into the cascading impacts of various congestion management strategies, much less

[11] The purpose of visual audits (conducted via field visits to observe/inspect congestion hotspots or specific ICM strategies in place along the corridor) is to provide a balanced understanding of congestion patterns and/or opportunities identified through the course of analysis of the archived data.

combinations of strategies, across the entire network, transportation modes, and facility types. Therefore, an integrated approach is often necessary to support management of corridor planning, design, and operations by combining the capabilities of existing tools.

For many regions, the existing tool that will be available will be the regional travel demand model. However, the regional travel demand model often possesses too large of a network to be successfully integrated with more detailed simulation models. Therefore, subareas and networks will likely need to be developed from the larger macro scale models to focus on the more micro-level corridor. Figure 3-8 presents a sample view of the cascading effect of corridor concentration in the various types of models.

Figure 3-8. Network Detail Examples for Different Model Types



[Source: Cambridge Systematics, April 2007.]

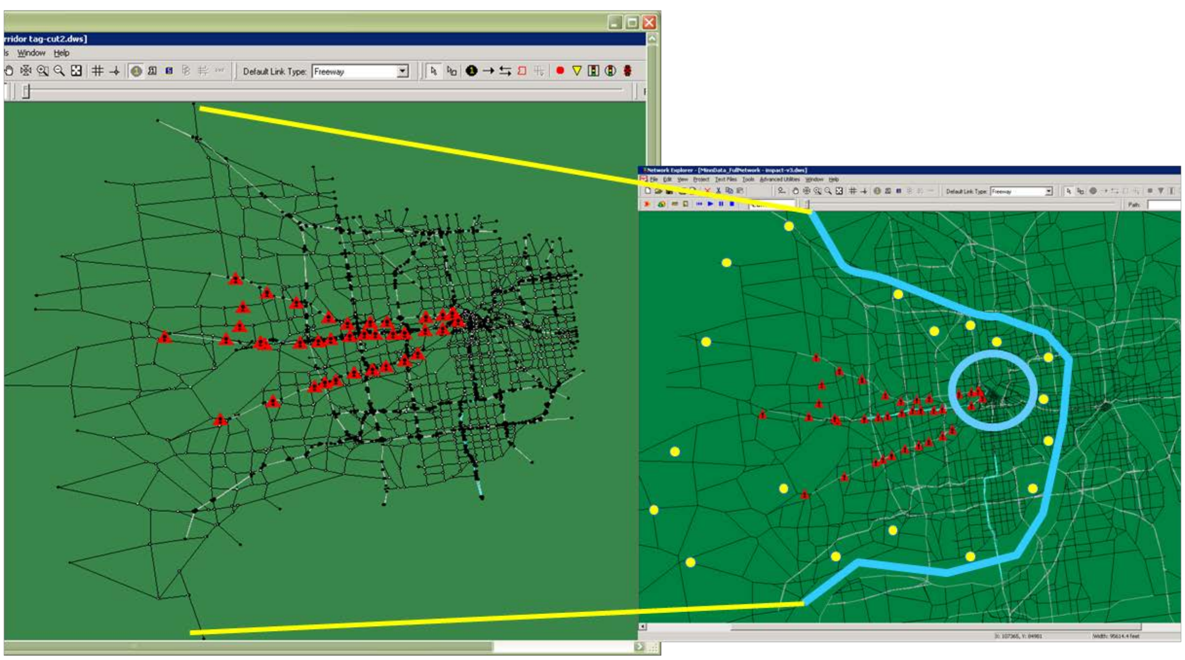
The first step in the model setup and calibration task is to identify the level of corridor network detail required for the selected analysis tools and begin extracting these networks from the regional travel demand model. The calibration and validation efforts are a critical step to ensuring that the base tables and models are representative of actual conditions so that the errors don't get carried forward in the process. In identifying and extracting the subarea network for integration in the more detailed simulation models, care is required to properly size the subarea network. Factors to be considered in the extraction of the model network include:

- Availability of network data in the regional travel demand model;
- Network size capabilities of the simulation model and desired processing times. Larger models (e.g., number of links, number of Origin-Destination zones) often can add complexity and analysis time to simulation models. Macroscopic and mesoscopic models will have dramatically different data demands and limitations than microscopic models;

- Modes being considered in the analysis and any specialized transit links;
- ICM strategies being considered and their likely impacts;
- Likely diversion routes within the corridor;
- Location of major multimodal transfer locations;
- Origin–destination patterns of corridor travelers. Conducting a select link analysis on the corridor may be useful in identifying these patterns;
- Jurisdictional boundaries and the need to segment out the performance measures according to these boundaries;
- Availability and quality of coverage of supporting network data that will need to be integrated into the simulation model (e.g., signal locations and timing plans); and
- Special Generators—known locations that create or attract large amounts of trips on regular or irregular schedules (e.g. factories with shift workers, schools, stadiums).
- Any additional specialized analysis or reporting needs.

Figure 3-9 shows an example of network extraction from the Minneapolis ICM Pioneer site. In this example, the regional travel demand model formed the basis for the extraction of a subarea network used in a mesoscopic model. Select link analysis was performed in the travel demand model to identify the appropriate detail in the origin-destination zones to include in the model and the appropriate aggregation/disaggregation scheme.

Figure 3-9. Subarea Network Cut (Left) and Original Network (Right)



[Source: Cambridge Systematics, September 2010.]

Once the appropriate baseline network has been identified for the AMS process, the next step is to build up this model network with the additional data needed to integrate this model in the selected simulation model. This additional data is likely to include traffic signal locations and timings as well as confirmation of roadway geometrics. For example, in the Dallas Pioneer Site, the baseline travel model data did not include coding for numerous auxiliary lanes throughout the corridor. These lane locations need to be confirmed (through online mapping/satellite photographic web sites) and manually coded into the baseline simulation networks. Once the initial baseline network development is complete, the next step is to develop and deploy the trip demand data. Depending on the results of this process, it may be necessary to return to the network development process to adjust parameters within the network to adjust the model.

It is important that quality control is performed as part of this workstep. Because of the detail involved in specifying network and traffic signal parameters, it is fairly easy for analysts to miss some of the critical details. A separate team (internal or external) should be assigned to conduct a quality control exercise in the baseline models developed in this step.

Substep 3.3: Conduct Demand Modeling for Existing Baseline Year

The next step in the model setup and calibration process is the determination of travel demand for the baseline period. This process includes the identification of corridor travel demand and the disaggregation of the peak-period trip tables from the travel demand model into more discrete time-period trip tables. The development and refinement of these corridor trip tables is typically performed in an incremental fashion, with trip tables being developed, tested, adjusted, and retested in subsequent steps until calibration is achieved in the following workstep.

The subtasks involved in determining travel demand for the baseline year includes:

a. **Develop trip tables for corridor subareas from the regional travel demand model –** Origin-destination trip tables are established for the subarea model. This requires the aggregation and disaggregation of zones into the identified simulation zone structure.

b. **Develop time-of-day distribution –** Peak-period trip tables are disaggregated into more discrete time slices. Archived data from automated traffic surveillance monitors is useful in this step to identify the average proportion of travel in the network at any given time.

c. **Conduct origin-destination matrix estimation** (ODME). This estimation is used to develop a balanced trip table for corridor study area.

Once the initial network and demand-level development has occurred for the simulation model, the calibration process is initiated. The calibration process is likely to require parameters and decisions made in the previous steps to be revisited as part of an iterative process to refine the simulation model.

Substep 3.4: Calibrate Simulation Model

Each simulation software program has a set of user-adjustable parameters that enable the practitioner to calibrate the model to better match specific local conditions. These parameter adjustments are necessary because no simulation model can include all of the possible factors (both on- and off-street) that might affect capacity and traffic operations. The calibration process accounts for the impact of these “unmodeled” site-specific factors through the adjustment of the calibration parameters, which is included in the software for this specific purpose. Therefore, model calibration involves the selection of a few parameters for calibration and the repeated operation of the model to identify the best values for those parameters. Calibration improves the ability of the model to reproduce local travel conditions accurately. The key activities in calibration are:

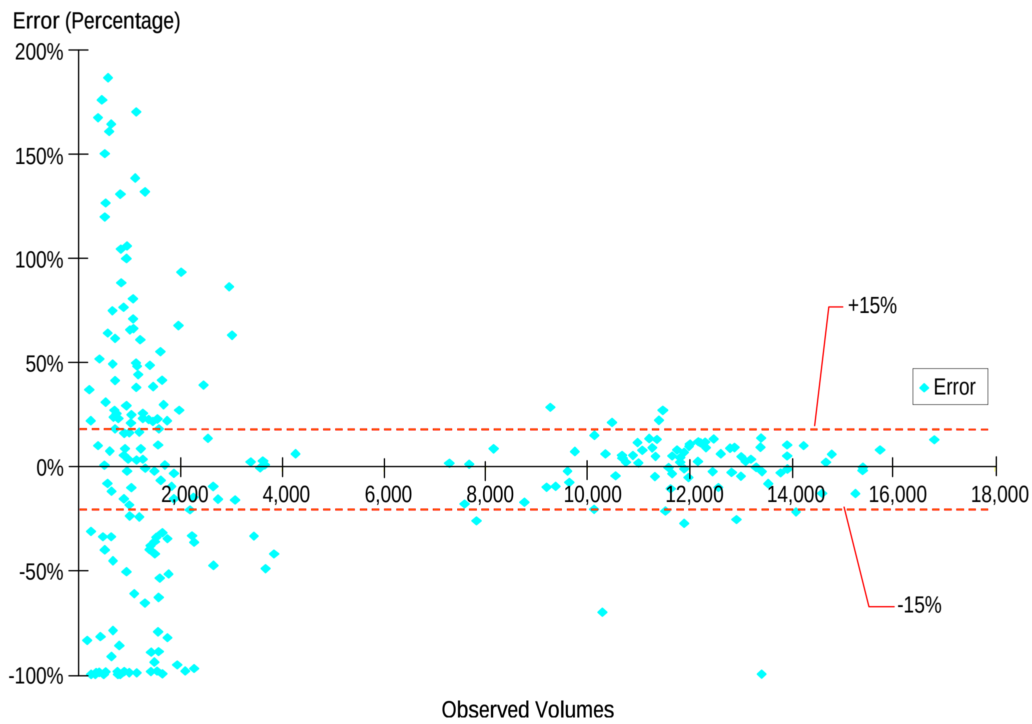
- Identification of necessary model calibration targets;

- 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; and
- Calibration of the overall model against overall system performance measures, such as travel time, delay, and queues.
- Documentation of the above four bullets.

This guidance is based on the three-step strategy recommended in the FHWA Guidelines for Applying Traffic Microsimulation Modeling Software.[12]

In calibrating the baseline scenarios, the model output performance measures need to be compared with the "ground-truth" measures. Figure 3-10 presents an example view of model output volumes compared with actual ground link volumes. Note that there is often great variation in model results for low-volume links. As shown in the calibration criteria presented in Table 3-9, deviations on links with peak period volumes of less than 2,000 are not included in the calculation of the acceptance targets.

Figure 3-10. Example of a Calibration Chart Showing Deviation in Model vs. Ground Link Volumes



[Source: Cambridge Systematics, September 2010.]

[12] Dowling, R., A. Skabardonis, and V. Alexiadis, *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*, FHWA-HRT-04-040, Federal Highway Administration, July 2004.

Once the baseline model is successfully calibrated according to the acceptance targets, the following additional calibration steps are required:

a. **Calibrate model for known incident conditions** – In this step, an incident is introduced and the simulation model's ability to successfully recreate the observed accident conditions is tested. This can be a complex process as it is often difficult to obtain suitable calibration data for an individual incident. For an incident, or nonrecurring congestion, the following example model calibration criteria were developed as part of the ICM AMS effort:
   - **Freeway bottleneck locations**. Should be on a modeled segment that is consistent in 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;
   - **Diversion flows**. Increase in ramp volumes where diversion is expected to take place; and
   - **Arterial breakdown when incident**. Cycle failures or lack of cycle failures.

b. **Validate roadway model** – In addition to the calibration of the model, it is important to ensure that the model can accurately recreate conditions observed from ground count measurement, The model must also be validated to check the input parameters and assumptions; in other words, it must pass a "reality check" when compared to known driver behaviors and human/vehicle limitations.

c. **Validate model for transit, HOV, and park-and-ride facilities –** In many ICM analyses it may also be critical to calibrate against multimodal targets.

d. **Summarize model calibration approach and findings in calibration/validation report** – The final step in the model calibration process is to document the approach to the calibration process, including criteria and acceptance targets used, output results, any unresolved errors (known issues), and lessons learned. These items should be detailed in the calibration/validation report.

Output

The output of this workstep includes:

- Baseline model networks and trip tables;
- Calibrated simulation model; and
- Calibration/validation report.

Timeframe

The development, refinement, and calibration of the analysis models are some of the most variable aspects in the study timeframe. Typically, this process may range anytime from approximately 2 to 10 months in duration. This workstep is often one of the most time consuming tasks to be completed in the AMS.

Challenges

Some challenges that may be encountered during this workstep are presented below.

- The development and calibration of the models is often the riskiest task to be completed in the AMS as it requires the greatest investment in time and resources. The AMS team must take special care to calibrate the model so that it replicates existing conditions (recurrent and nonrecurrent traffic congestion as well as transit system performance) data as closely as possible. Errors resulting from misspecification (for example, not gathering concurrent data as discussed previously) or incorrect expectations (for example, by relying on anecdotal perceptions of corridor problems rather than archived data) can have a significant impact on project budget and timeframe. Failure to suitably invest resources in this task can result in models that are incapable of providing the correct assessment of ICM impacts, thus requiring that this workstep be repeated at significant cost.

- Analysis of incidents and ICM strategies may require the expansion of the "typical" peak periods evaluated in the travel demand models. Additional time may be required for incident and heavy demand traffic to dissipate in the simulation models. The addition of time to the shoulders of the peak period may be necessary to properly assess traffic conditions during the buildup and dissipation of congestion. For example, in the analysis of the Pioneer Sites ICM, the morning analysis period was expanded to a period from 5:00 a.m. to 11:00 a.m. to provide adequate shoulders to the peak period.

- All stakeholders need to participate in the development and review of the model calibration settings. The technical modeler responsible for the development of the model may not know the actual conditions of the roadway and will likely not know how to calibrate the model. Model calibration is a collaborative step between the operational corridor managers and the modeling team.

- The need to calibrate and validate the developed models correctly cannot be understated. The correct calibration of the models will influence the accuracy of the model outputs and animation and will ultimately determine the success of the analysis approach.

Resources

Managers are encouraged to reserve approximately 30-40% of their total project budget for Workstep 3: Model Calibration. The quality of the two preceding steps will facilitate greater ease with this workstep; however, calibration involves a certain amount of trial and error which must be accommodated in the AMS budget and planning. The technical modelers will play primary roles in this workstep. Managers must have an understanding of the overall calibration methodology and criteria.

3.4 Workstep 4: Alternatives Analysis and Documentation

Objective and Value

The objective of this workstep is to develop the alternative scenarios within the models developed and calibrated in the previous step. These alternative scenarios will be analyzed and the results documented according to guidelines provided in the analysis plan.

As previously pointed out in this guide, the robust data available from the AMS and the integrated benefit/cost analysis provide critical feedback to system designers and operators to allow them to steer their investment into the right strategies. This objective of the AMS not only includes the major investment decisions (i.e., prioritizing and selecting the right mix of strategies to deploy), but also includes the ability to assist planners and operators in devising appropriate operating parameters and concepts of operation to optimize the impacts of the selected strategies.

AMS allows planners and operators to maximize their investments in their ICM strategies by allowing for the analysis of various “what if” scenarios to test different operational schemes, parameters, and concepts in order to optimize the efficiency of the integrated systems. AMS allows for these “what if” scenarios to be tested, modified, and refined without having to resort to real-world experimentation, in which any mistakes would have high costs. AMS also allows for these operational strategies to be tested and refined for conditions that happen infrequently, allowing for different strategies to be analyzed and compared simultaneously.

The ability to analyze various conditions and test different operational parameters under these varying conditions helps operators identify deficiencies in their operational plans, which would result in inefficiencies in operating the ICM. Different modifications and refinements may then be tested and compared using AMS and benefit/cost analysis to develop optimal plans for maximizing the efficiency of the ICM investment.

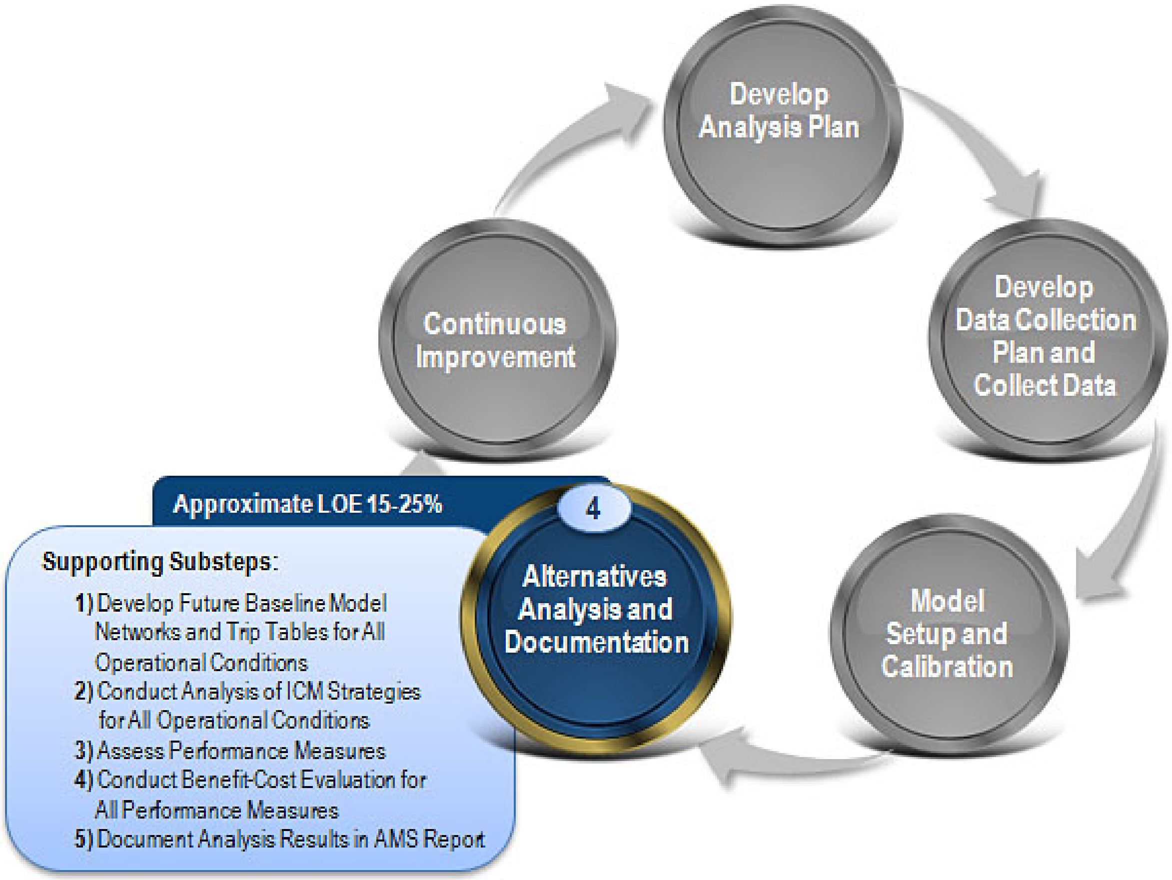
As an example of this refinement process, the ICM CONOPS for the San Diego Pioneer site initially called for opening the managed lanes to all traffic during major incidents on the I-15 corridor. Studying this operational concept in the AMS revealed, however, that opening the managed lane during incident conditions would increase the travel times for the planned Bus Rapid Transit (BRT) deployment, thus making it a less attractive option for travelers, and would keep many travelers from switching modes from their personal autos, exacerbating the incident-related congestion. This situation was revealed by carefully studying the output for the various modes evaluated in the AMS and discovering that the benefit/cost analysis revealed fewer benefits than anticipated. As a result, the San Diego ICM planners and operators scrutinized their operational plans during major incidents and formulated a number of “what if” scenarios by modifying assumptions regarding the operation of different strategies. They made adjustments to managed lane prices, BRT fares, ramp metering rates, and other operational levers under the control of corridor operators. The different operating parameters were analyzed and tested using AMS, and the different scenarios were refined through several iterations of analysis, comparison, and adjustment until the resulting operational assumptions and parameters produced the most optimal level of performance (minimizing delay), thus maximizing the effectiveness of the ICM investment.

The successful completion of this workstep will result in a prioritization of potential ICM investments and a clear communication of the potential project benefits. This workstep represents the culmination of all of the previous worksteps, and the results can be used by the ICM deployment team to shape investment decisions and to secure deeper and broader support for the ICMS among stakeholder organizations (executive agency leaders and managers, planners, operators, analysts and engineers in these organizations) and elected officials. AMS managers are encouraged to work with communications professionals to translate technical results into accessible visual and “soundbite” messages that can be shared broadly.

Approach and Substeps

Figure 3-11 presents an overview of the substeps related to the alternatives analysis.

Figure 3-6. Overview of Workstep 4: Alternatives Analysis and Documentation



[Source: Research and Innovative Technology Administration and Cambridge Systematics.]

The following substeps comprise the alternatives analysis and documentation workstep:

Substep 4.1: Develop Future Baseline Model networks and Trip Tables for All Operational Conditions

Once the existing baseline model has been calibrated, the AMS team can then proceed to obtain the future year model networks and trip tables from local agencies (i.e., MPOs) and develop the future baseline model. The analysis plan defines all the alternative scenarios that need to be analyzed in this task. Model networks and trip tables should be modified according to the analysis plan guidelines to simulate the scenarios and the impact of the ICM strategies.

Substep 4.2: Conduct Analysis of ICM Strategies for All Operational Conditions

The models and related analysis should be conducted using the modified networks and trip tables developed in the previous step. This may include multiple model runs for each scenario, depending on whether analysts want to conduct additional verification of results (i.e., assure results generally are within expected realms [for example that VMT results are approximately the same as the baseline]) and investigate counterintuitive results. All analysis runs should be adequately documented to ensure to application of the correct inputs and assumptions according to the analysis plan.

Supporting steps for conducting this operational analysis include:

1. *Evaluate the initial operational assumptions using AMS, scrutinizing the results for any underperforming or counterintuitive metrics.*
2. *Brainstorm a number of causes for the underperformance and a potential set of "what if" adjustments that might be made to alleviate the deficiencies.*
3. *Formulate a set of scenarios that may be evaluated in the AMS structure to assess the impacts and benefits of adjustments to the operational assumptions.*
4. *Analyze, compare, and refine – and re-run through the AMS procedures as necessary – to identify the optimal operating parameters.*
5. *Document the tested scenarios and results for potential future use.*
6. *Re-conduct the refinement process in a continual feedback loop as future conditions change or encountered deficiencies are warranted.*

Following these steps will help to ensure that the AMS results not only in the identification of the appropriate technologies and strategies to deploy, but also that the strategies are operated in the manner that best optimizes the investment in ICM.

Substep 4.3: Assess Performance Measures

In this step, the analysts assess the results of the previous step in light of the performance measures defined in the analysis plan. Below is a summary of how the basic types of performance measures defined in the analysis plan can be calculated to gain insight into overall benefits of ICM to corridor performance:

- **Mobility**. Three primary types of measures were used in the analysis plan to quantify mobility: travel time, delay, and throughput. Travel time and delay are fairly straightforward to calculate using model outputs. Throughput is calculated by comparing travel times under the incident scenarios to those under no incident – by comparing the percentage of trips under the same threshold travel time in both the pre- and post-ICM scenarios, the relative influence of ICM on reducing extreme travel times can be estimated.[13]
- **Reliability and Variability of Travel Time.** Travel time reliability/variability is reported in terms of changes in the Planning Index and changes in the standard deviation of travel time.
- **Emissions and Fuel Consumption**. Estimates of this can be produced by using emissions and fuel consumption rates based on factors, such as facility type and vehicle mix combined with model output such as travel speed.
- **Safety.** Available safety analysis methodologies are not sensitive to ICM strategies. At best, available safety analysis methods rely on crude measures, such as V/C, and cannot take into account ICM effects on smoothing traffic flow. Clearly, this is an area deserving new research. As such, no explicit safety analysis needs to be conducted as part of this effort.
- **Cost Estimation.** Planning-level cost estimates can be prepared, including life-cycle costs (capital, operating, and maintenance costs). Costs can be expressed in terms of the net present value of various components. Annualized costs represent the average annual

[13] ICM AMS analysis defines corridor-wide throughput differently than the usual point definition of vehicles per unit time. See Appendix A for the detailed definition.

expenditure that is expected in order to deploy, operate, and maintain the ICM improvement and replace equipment as it reaches the end of its useful life.

In many AMS cases, the incremental changes resulting from the deployment of a particular ICM strategy will need to be summed from multiple test scenarios in which the strategy was deployed. ***This sum of changes should be weighted across the multiple test scenarios to reflect the likelihood of the scenario happening (i.e., the frequency in which the scenario would be expected to occur).*** This scenario weighting scheme should be developed and documented in the analysis plan (as discussed in Chapter 3.1 of this guide). To the extent that every operational condition does not have the same probability of occurring, the AMS team will want to assign relative weights to the alternatives accordingly. For example, a corridor may experience incidents approximately 30 percent of the time on freeways, of which approximately 20 percent are what would be characterized as "major" incidents. Major incidents under conditions of "high demand" could occur only 5 percent of the time, but create significant congestion on the corridor. The analysts would want to be sure to assign a relative weighting scheme that reflects this. Table 3-10 shows an example display from Dallas of the incremental change in performance measures estimated using AMS.

Table 3-9. Example Summary of Performance Measure Analysis Output

Performance Measure	Pre-ICM	Post-ICM	Change	Percent Change
Average Travel Time (Minutes/Traveler)				
All Routes	17.59	17.56	-0.03	-0.2%
Average Delay (Minutes/Traveler)				
All Routes	6.93	6.90	-0.03	-0.4%
Total Delay (Person-Hours)				
All Routes	235,106	234,145	-960	-0.4%
Planning Index				
All Routes	4.59	4.54	-0.05	-1.0%
Variance in Travel Time (Minutes^2)				
All Routes	15.29	14.83	-0.46	-3.0%
Trips Using U.S. 75 SB	21.35	19.91	-1.44	-6.7%
Trips Using U.S. 75 NB	8.16	7.81	-0.35	-4.3%
Passenger Hours Traveled				
All Routes	596,737	595,687	-1,049	-0.2%
Passenger Miles Traveled				
All Routes	17,393,765	17,394,135	370	0.0%
Passenger Miles Delivered (by 11:00 AM)				
All Routes	16,456,147	16,456,721	574	0.0%
Trips Using U.S. 75 SB	2,595,363	2,601,746	6,383	0.2%

[Source: Dallas U.S. 75 ICM AMS Final Report, 2011.]

Substep 4.4: Conduct Benefit-Cost Evaluation for all Performance Measures

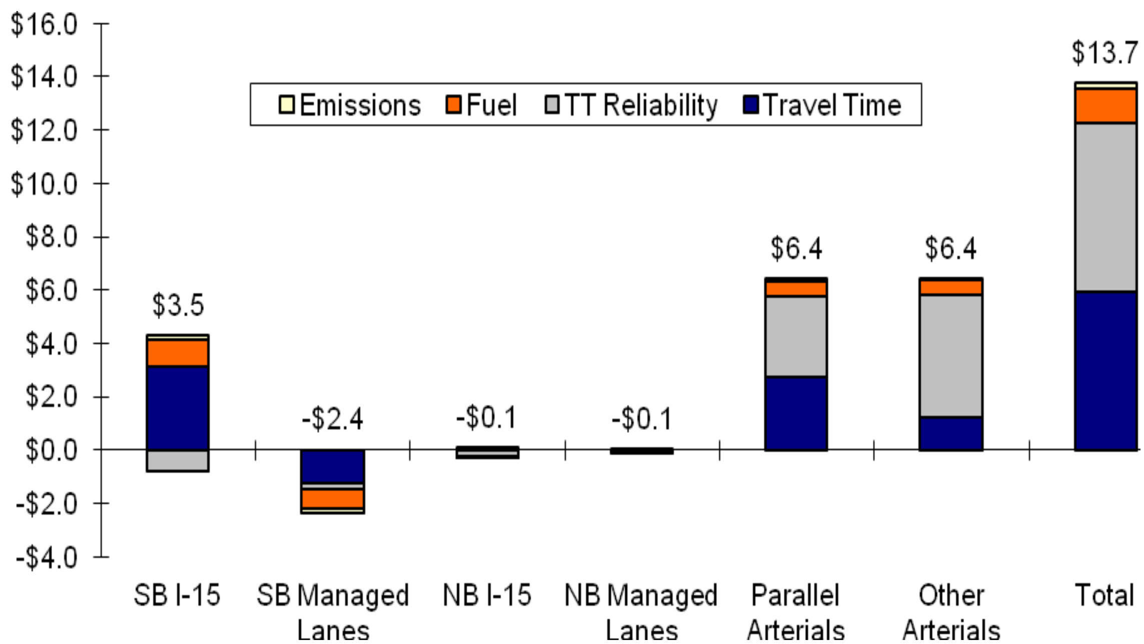
Benefits should be estimated for the improvements by monetizing the incremental change in performance measures associated with the ICM strategies and scenarios analyzed. The incremental change in the performance measure should reflect the weighted sum of changes for all analysis scenarios. The results of this analysis should enable the AMS team to assess the optimal strategies, or combinations of strategies, that can deliver the greatest impact on the corridor's transportation objectives for the cost.

A benefit/cost analysis is a rich analytic method in its own right, with its own supporting literature, and should be undertaken carefully. A properly calculated benefit/cost analysis will monetize metrics that are comprehensive, mutually exclusive, and designed to render all effects to the appropriate side of the ledger as either a cost or a benefit.

To estimate the benefits in annual dollar values, the annual incremental change in the various performance measures should be multiplied with an estimate of the monetary value of benefits (e.g., the value of an hour of travel time saved). Monetary values of benefits (e.g., value of time, value of accident reduction) should be consistent with those values typically applied in the region. For those performance measures with no established local value, national benefit valuations may be applied. A potential source for these benefit values is the user manual appendices to the FHWA developed ITS Deployment Analysis System (IDAS) tool. This documentation can be found at: http://idas.camsys.com/. Additionally, FHWA is currently developing guidance for conducting benefit/cost analysis for Operations strategies to be compiled in the Operations Benefit/Cost Desk Reference. This documentation is anticipated to be available in late 2011.

Figure 3-12 presents an example view from San Diego of the annual benefits of an ICM summarized by performance measure and facility type.

Figure 3-7. Example Display of ICM Benefits by Facility



[Source: San Diego ICM AMS Final Report, 2011.]

For the identified ICM strategies, planning-level cost estimates will need to be prepared, including life-cycle costs (capital, operating, and maintenance costs). Costs need to be expressed in terms of an annualized cost or the net present value of various components over a given time horizon (e.g., 20 years) and are defined as follows:

- **Capital Costs –** Include up-front costs necessary to procure and install ICM equipment. These costs will be shown as a total (one-time) expenditure, and will include the capital equipment costs as well as the soft costs required for design and installation of the equipment.

- **Operations and Maintenance (O&M) Costs –** Includes 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 will be 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 Pioneer Corridor ICM deployments.

The complexity of these deployments warrants that these cost figures be further segmented to ensure their usefulness. Within each of the capital, O&M, and annualized cost estimates, costs should be 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 closed-circuit television (CCTV) 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. Analysts should be careful to include incremental costs of infrastructure created by issues of scale. For example, if the traffic management center CCTV infrastructure has the bandwidth to support 30 cameras but the deployment being analyzed would take the number from 25 to

35, then some incremental infrastructure cost would be incurred beyond the incremental camera costs themselves.

Structuring the cost data in this framework enables the user 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. Presenting the costs in this scalable format provides the opportunity to easily estimate the costs of expanding or contracting the size of the deployment and allows the cost data to be reutilized for evaluating other corridors.

Substep 4.5: Document Analysis Results

Upon completion of the alternatives analysis, the results should be documented in a summary AMS Report. This document should build upon data contained in the analysis plan, the data collection plan, and the calibration/validation report. The summary AMS Report should function as a stand-alone document that fully encapsulates the process and the results of the AMS. See the AMS Reports produced by the ICM AMS Pioneer Sites for examples of this documentation.

In creating the AMS Report, the AMS manager should refer back to the analysis plan documentation to ensure that all anticipated analyses have been successfully performed and document any deviations from this plan. The AMS Report should also contain documentation of lessons learned through the completion of the alternatives analysis. Table 3-11 shows an example comparison of high-level ICM AMS outputs from the three Pioneer Sites.

Table 3-10. Comparison of ICM AMS Outputs From the Three Pioneer Sites

	San Diego	Dallas	Minneapolis
Annual Travel Time Savings (Person-Hours)	246,000	740,000	132,000
Improvement in Travel Time Reliability (Reduction in Travel Time Variance)	10.6%	3%	4.4%
Gallons of Fuel Saved Annually	323,000	981,000	17,600
Tons of Mobile Emissions Saved Annually	3,100	9,400	175
10-Year Net Benefit	$104M	$264M	$82M
10-Year Cost	$12M	$14M	$4M
Benefit-Cost Ratio	10:1	20:1	22:1

[Source: ICM AMS Stage 2 Pioneer Sites Executive Summary, 2011.]

Output

The primary outputs from this workstep include:

- Performance measures for all alternatives;
- Benefit/cost analysis for each alternative; and
- A prioritized list of response strategies for each scenario.

These outputs should all be documented in the final ICM AMS report, along with any additional lessons learned in the alternatives analysis process.

Timeframe

The length of the alternatives analysis varies based on the number and complexity of the test scenarios to be analyzed. Depending on the complexity of the model and the available computing resources, the physical act of running the alternative through the model may take 24 hours or more. These model results then need to be evaluated, and the alternative may need to be run again if discrepancies are noted. It is important that these time demands be carefully considered in planning the number of alternatives that may be reasonably evaluated in the time available. The analysis of alternatives would typically be expected to take approximately 1 to 4 months, with at least one additional month needed to develop the AMS report.

Challenges

Some challenges that may be encountered during this workstep of the AMS are described below.

- In assessing the model results, the analysts need to weigh the model outputs carefully against the expected outcomes identified in the analysis plan. Where discrepancies exist, further scrutiny is required to assess whether the unexpected outcomes are a result of discrepancies in the model or whether the expected outcomes were not realistic. If the analyst determines that strange model results are a result of model discrepancies, modifications to input parameters may be considered and the alternative rerun; however, it is critical that any modifications to the model inputs be carefully documented and presented in the AMS Report.

- The AMS is designed to provide for an accurate assessment of ICM impacts on performance measures. However, the interpretation of the analysis results often relies on human assessment. Care should be taken to reduce the risks of introducing bias into the interpretation of results by not giving too much weight to analysis capabilities that are not inherent in the AMS. The analysts should make a significant effort to fully understand the capabilities and limitations of the models and the datasets in order to objectively interpret the results.

- The time, staffing, and computing resources required to complete this task can be significant. The analyst managers are encouraged to plan carefully for these resources prior to initiating this task and to provide sufficient flexibility in scheduling these resources to address unforeseen issues that may arise during the workstep completion.

Resources

Workstep 4: Alternatives Analysis and Documentation may represent up to 15-25% of the total work effort for AMS, presuming the preceding steps have been comprehensively implemented. This workstep requires intensive involvement of both technical modelers and technical project managers of the ICM and/or ICM AMS initiative who have deep understanding of the operational objectives of the proposed ICM strategies. These individuals work collaboratively to assess the various operational alternatives. A critical dependency for this task is a robust Analysis Plan.

3.5 Workstep 5: Continuous Improvement

Objective and Value

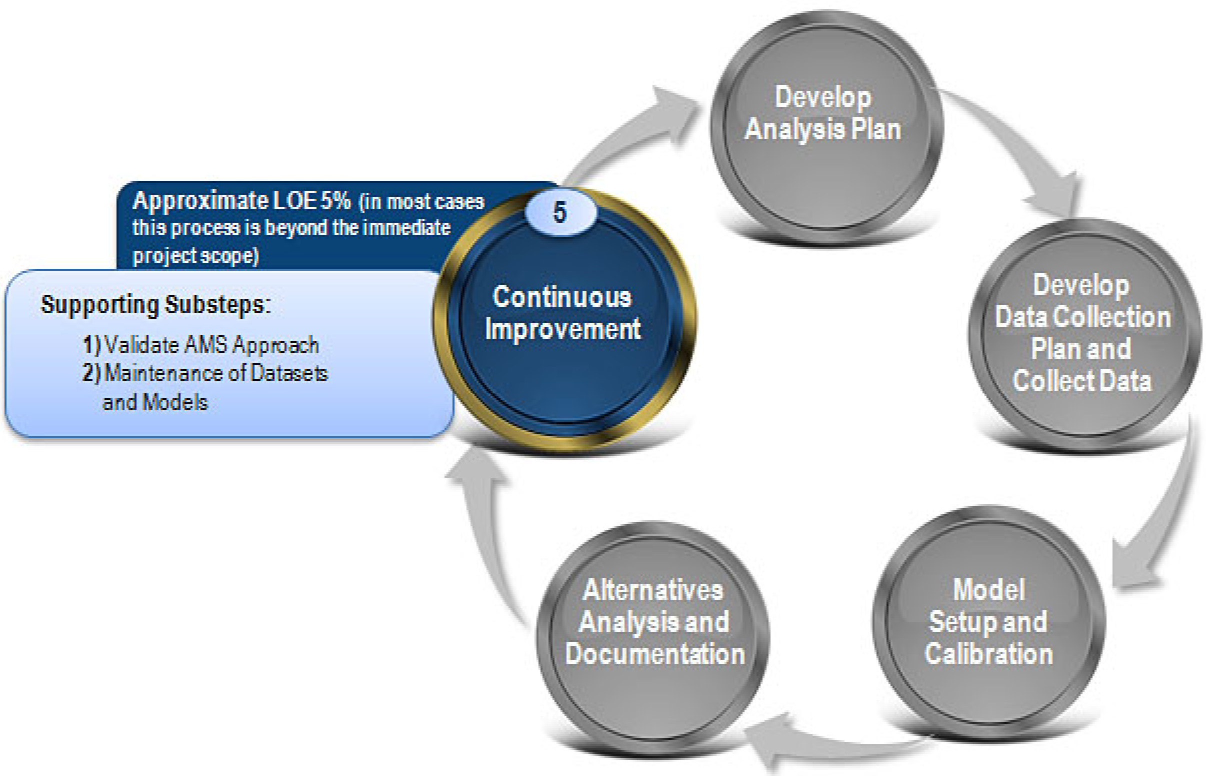
The objective of this workstep is to gather lessons learned throughout the completion of the AMS and inject these back into the process in order to provide continual improvement of the ICM corridor and future ICM strategy analysis. The analytical capital accumulated through this continual improvement process serves not only to improve the analysis that is currently being conducted immediately, but also to enhance analytical capabilities for future analysis of strategies and investments.

Given the dynamic nature of traffic congestion on many corridors, it is likely that the AMS process will need to be repeated in the future—perhaps as often as every 5 years—in order to adjust the ICM components to current conditions. The completion of the continuous improvement workstep ensures the maintenance of the models and datasets, greatly reducing the costs, enhancing the ease with which future analyses may be performed on the corridor, and improving the effectiveness in which future investment decisions are made.

Approach and Worksteps

Figure 3-13 presents an overview of the subtasks and worksteps related to incorporating continuous improvement into the AMS process, as documented in the analysis plan. The figure also provides a summary of where this process relates to other recommended worksteps in the AMS. Subsequent discussions provide additional detail on the recommended execution of the identified subtasks.

Figure 3-8. Overview of Workstep 5: Continuous Improvement



[Source: Research and Innovative Technology Administration and Cambridge Systematics.]

The approach for this workstep involves efforts throughout the lifecycle of the AMS; however, several key activities occur after the completion of the analysis and the deployment of the selected ICM strategies. These efforts include:

Substep 5.1: Validate AMS Approach

This assessment should include:

- Reassessment of the models, calibrations, and results based on ICM deployment. An assessment of the AMS approach should be completed once the ICM deployments have been effectively implemented. Where possible, AMS managers should compile data regarding the actual, ground-truth impacts related to the ICM deployments to provide a comparison between model-predicted values and actual observed values. Likewise, changes observed between the future baseline forecasts and actual future conditions should be analyzed. The data gathered may be used to adjust the models and tools in order to improve the analysis capabilities of the tools.

- Identify good practices and lessons learned. Determine which AMS procedures worked as well as those that did not. Whenever possible, any external factors that influenced the success or failure of particular practices should likewise be documented.

Substep 5.2: Maintenance of Datasets and Models

The AMS represents a significant investment by the implementing agency. The processes and tools developed for the AMS have numerous potential future applications. Therefore, the datasets and tools developed for the AMS should be carefully archived. Data dictionaries and user guides should be developed in parallel to assist in the future use of the AMS outputs. Given the dynamic nature of many corridors, it is likely that the AMS will need to be performed again in future years to adjust the ICM strategies to changing travel conditions. Further, if the ICM deployment is proven to have significant benefits, there are likely to be calls to expand the corridor or apply the strategies to additional corridors in the region. Therefore, proper maintenance of the models and datasets will ensure that these future analyses can be performed at a greatly reduced cost and with improved ease of application. The maintenance of the models and datasets may require a mindset change for some agencies unaccustomed to these activities; however, the investment has significant benefits.

Output

Output for this workstep includes:

- Technical memo summarizing findings from this assessment, including “lessons learned” throughout the completion of the project. These findings can be used to update future analysis plans.

- Complete archive of models and datasets on some durable medium, preferably in one location.

- All AMS tools and datasets should be accompanied by sufficient documentation and data dictionaries to guide their future use by personnel outside of the current AMS effort.

Timeframe

These tasks should be completed throughout the life cycle of the AMS, and lessons learned should be documented so they may be used going forward in ongoing performance measurement and future ICM AMS.

Challenges

Some challenges that may be encountered during this workstep are summarized below.

- There is a tendency to want to forego this feedback task once the major analysis tasks have been completed. However, this task is absolutely critical to improving AMS. Therefore, the resources necessary to complete this ongoing task should be planned for in the analysis plan, and AMS managers should devote adequate effort to ensure its full and successful completion.

- Conducting this workstep may require a mindset change for some agencies unaccustomed to these activities. Continuous improvement may require changes to agency policies, work habits, and data processes and systems.

Resources

This final step is ongoing, and represents approximately 5% of the typical project budget (in most cases this process is beyond the immediate project scope). Implementation of the preceding steps in a systematic fashion positions stakeholders to derive long-term value from ICM AMS. The AMS tools are able to be readily updated and adapted to support other decision support needs to continually improve corridor performance.

Chapter 4 ICM AMS Lessons Learned

The ICM AMS process was developed in close coordination with the ICM Stage 2 Pioneer Sites, including Dallas (U.S. 75), Minneapolis (I-394), and San Diego (I-15). Lessons learned throughout the development and refinement of this process have been incorporated into this guide. General conclusions regarding the benefits resulting from this process development are summarized below.

4.1 The Role of AMS

- The AMS process provides an invaluable framework for conducting assessments of the potential impacts and benefits of ICM strategies. The analytical complexity involved in these types of assessment goes far beyond what is typically required for more traditional types of transportation investments. The potential inclusion of multiple facility types (freeway and arterial) and multiple modes, combined with the potential influence of congestion pricing, complicates the analysis. The focus of the ICM strategies on non-typical operations scenarios (e.g., high demand, incidents, inclement weather) adds further complexity to the assessment. The AMS procedures provide a pragmatic roadmap to guide practitioners through this complexity while not being too rigid to allow for flexibility in addressing project contingencies.

- The completion of the AMS helped to identify deficiencies in the design process that would not have been identified prior to deployment. This would have resulted in issues arising during actual deployment and costly modifications to correct the deficiencies.

- The AMS analysis identified key prospective benefits from proposed ICM improvements to the Pioneer sites, including:
  - Improved mobility;
  - Improved travel time and decreased delay post implementation;
  - Improved travel-time reliability;
  - Reduced fuel consumption and mobile emissions; and
  - Relatively greater benefits at higher levels of travel demand and during nonrecurrent congestion.

- The Pioneer Sites reported that using the AMS not only improved their analysis capabilities for the ICM evaluation, but also served to enhance many existing tools and capabilities that can be applied to analysis of other investments. This analytical capital will enhance future analysis and increase confidence in the models. Some of the improvements reported by the Pioneer Sites included new software modules for analysis of multimodal assignment (transit), congestion pricing, HOT lanes, ramp metering, and real-time decision support systems.

Pioneer sites also cited improved data quality control methods and enhanced model calibration procedures as examples of the continuous improvement benefits of the AMS process.

- The unique and innovative nature of ICM requires that AMS be continually refined and improved. More data is constantly becoming available and new lessons that can be used to improve the process are constantly being learned.

4.2 AMS Framework and Methodology

- **Different tool types have different advantages and limitations.** There is no one tool type at this point in time that can successfully address the analysis capabilities required by ICM AMS requirements. There is no single model available that provides visibility into the cascading impacts of various congestion management strategies, much less combinations of strategies, across the entire network, transportation modes, and facility types.
- **An integrated approach can support corridor management planning, design, and operations by combining the capabilities of existing tools.** The integrated approach is based on interfacing between travel demand models, mesoscopic simulation models, and microscopic simulation models. This approach may present integration challenges that can be addressed by identifying interface requirements that focus on maintaining consistency across both the analytical approaches used among the different tools and the performance measures used among the different tool types.
- **Key modeling gaps** in the existing tools' capabilities include: a) the analysis of traveler responses to traveler information, b) the analysis of strategies related to tolling/HOT lanes/ congestion pricing, and c) the analysis of mode shift and transit.

4.3 Data and Performance Measures

- Performance measures necessary for the AMS may require the collection of datasets that are unfamiliar to the managing agency. The AMS manager should seek out peer information on collecting this data for all new or unfamiliar data requirements.
- Many ICM strategies' focus on nonrecurring congestion may require the development of datasets focused on travel-time reliability and factors influencing nonrecurring congestion (e.g., incident occurrence or weather conditions). Automated data sources are often best for collecting the long-term data necessary to assess these nonrecurring performance measures; however, many existing automated data collection systems may lack the robustness or reliability to effectively compile relevant data sets. A thorough assessment of the data quality from all sources is recommended to identify any potential problems early on in the process and establish methods to address any deficiencies.
- Data for AMS is required to be collected concurrently – collected for the same dates and times across all modes and facilities. This is often different from typical planning data collection efforts that are assembled from data compiled from different dates and times. The

demands for concurrent data can require additional effort to coordinate and synchronize the multiple data collection efforts.

- Data quality from automated data sources (e.g., roadway loop detectors) may sometimes be insufficient for modeling purposes. Sample datasets should be obtained early in the data collection process and analyzed to assess data quality. The data collection plan should specify data quality procedures and minimal data quality requirements for this purpose. Further, AMS managers should discuss any data quality issues with operations personnel familiar with the data source during the development of the data collection plan in order to understand and anticipate any problems with data source reliability, data accuracy or other condition specific issues (e.g., inaccurate speeds recorded during high volume periods).

- It is critical the datasets be archived and maintained, along with all data dictionaries and supporting information, according to the data maintenance plans defined in the data collection plan. Failure to do so can result in a loss of data and the loss of resource investment in the data collection task.

4.4 Model Development

- **The development and calibration of the models is often the riskiest task to be completed in the AMS** as it requires the greatest investment in time and resources. Errors resulting from flawed specifications, incorrect expectations, or pure ignorance can have a significant impact on project budget and timeframe. Failure to invest suitable resources in this task can result in models that are incapable of providing the correct assessment of ICM impacts, with the result that this workstep must be repeated at significant cost.

- **Analysis of incidents and ICM strategies may require the expansion of the “typical” peak periods evaluated in the travel demand models**. Additional time may be required for incident and heavy-demand traffic to dissipate in the simulation models. The addition of time to the shoulders of the peak period may be necessary to assess traffic conditions properly during the buildup and dissipation of congestion. For example, in the analysis of the Pioneer Sites, the morning analysis period was expanded to encompass the period from 5:00 a.m. to 11:00 a.m. to provide adequate shoulders to the peak period.

- **In assessing the model results, the analysts need to weigh the model outputs against the expected outcomes identified in the analysis plan carefully**. Where discrepancies exist, further scrutiny is required to assess whether the unexpected outcomes are a result of discrepancies in the model or were due to unrealistic expectations. If the analyst determine the strange model results are a result of model discrepancies, modifications to input parameters may be considered and the alternative rerun; however, it is critical that any modifications to the model inputs be carefully documented and presented in the AMS report.

4.5 Continuous Improvement

- **The maintenance of models and datasets following the completion of the study may require a mindset change for some agencies**. Many agencies are unaccustomed to maintaining this intellectual capital following the completion of a major study; however, the investment in the maintenance and continuous improvement of the AMS has significant benefits, including reduced future analysis costs and improved decisionmaker effectiveness.

- **Practitioners are encouraged to utilize the significant levels of support that exist for AMS**. The USDOT has developed significant guidance in the form of this guide, the FHWA Traffic Analysis Toolbox initiative, and numerous other support mechanisms. Practitioners are also encouraged to learn from the experiences of the ICM Pioneer Sites by reviewing existing documentation and peer-to-peer contact.
- **Practitioners are encouraged to share information regarding their own experiences using AMS to plan for ICM**, particularly lessons learned that would be valuable to future agencies considering the approach. This guide is the result of early adopters of ICM strategies (i.e., the Pioneer Sites) sharing information. Although these early experiences have been valuable, there is still much to be learned. Through continual improvement, the ICM AMS will become more effective for all users.

APPENDIX A. USDOT Guidance on Performance Measures

A.1 Calculation Procedures for Key Integrated Corridor Performance Measures From Simulation Outputs

One contribution of the USDOT ICM Program has been the definition of a set of key national corridor performance measures consistently applied across multiple ICM sites. These measures represent the bottom-line for ICM strategy cost-benefit evaluation and have been instrumental in supporting a discussion of how ICM impacts can be best characterized among key corridor stakeholders. Initially, the discussion on performance-driven corridor management among the participating ICM Pioneer Sites was focused on measures derived from observed data. In the AMS phase of the effort (2009-10), however, attention turned to producing comparable measures derived from the outputs of different traffic simulation tools. This paper documents the algorithmic process developed in the ICM program and used to calculate key national measures of corridor performance. Throughout the AMS phase, these processes have been refined, coded and successfully implemented in the three participating AMS sites applying the ICM AMS methodology using three different analytical tools (Minneapolis, Dallas, and San Diego). The resulting algorithms offer a practical and broadly-applicable method of calculation, while breaking new ground in the definition of mode-independent, trip-based measures of aggregate corridor performance with explicit consideration of probability-weighted operational conditions.

This appendix provides a detailed description of how measures of ***delay***, ***travel time reliability*** and ***throughput*** are calculated from simulation outputs. A brief discussion of travel time variance is also provided given that travel time variance measures are used in ICM-related benefit-cost calculations. The algorithmic approaches defined here are software independent; that is, this process can be implemented with outputs from any of the time-variant simulation tools utilized in the three participating ICM AMS sites. The appendix begins with a discussion of the challenges in ICM corridor performance measurement. Next, we provide detail on the calculation of travel time, which informs both a calculation of delay as well as travel time reliability. Then, we provide a discussion of how corridor throughput is defined and measured. The appendix concludes with a discussion of how these measures are used to make comparisons between system performance in the pre-ICM case and in one or more distinct post-ICM cases.

Background

One critical aspect in ICM impacts assessment is the systematic consideration of atypical corridor operational conditions involving combinations of incidents, weather and variations in travel demand. This systematic consideration follows the technical approach developed in Bunch *et al.*,[14] wherein a cluster analysis of concurrent demand count, weather and incident records yields a set of operational condition scenarios, each with a probability of occurrence. This set of scenarios are implemented in traffic simulation by the modification of travel demand inputs to reflect variations in travel demand, the

[14] Bunch, J., Hatcher, S., Larkin, J., Nelson, G., Proper, A., Roberts, D., Shah, V., and Wunderlich, K., Incorporating ITS into Corridor Planning: Seattle Case Study, August 1999. EDL#11303.

tailoring of exogenous incident input files to reflect underlying incident patterns, and in the alteration of traffic flow parameters to represent the impact of weather. Calculation of the national ICM measures required incorporating this concept of operational conditions in all measures.

Another specific requirement of ICM corridor evaluation included the explicit treatment of multimodal trip making, and the impact of traveler choice on corridor performance. It was clear that addressing measure calculation from the traditional facility-centric perspective would be incapable of capturing ICM effects. Current guidance on reliability measures[15] focuses primarily on the utilization of observed data and the calculation of travel time and reliability measures for individual roadway facilities. Aggregation of facility level data by using simple volume-weighted methods were identified as both inaccurate and insufficient for the characterization of ICM impacts, particularly with respect to travelers who alter mode, time of departure and route in response to varying operational conditions. Federal guidance on performance measurement using traffic simulation models identify a set of recommended measures, but no detailed method of calculation.[16]

In order to fill this gap for the program, Noblis researchers were tasked with facilitating a discussion among the three ICM AMS sites and the national ICM AMS consultant (Cambridge Systematics) regarding the development of consistent, unambiguous measures that could be applied in all three ICM AMS sites. Each site used a combination of (static) travel demand modeling and linked traffic simulation to reflect ICM impacts. However, mesoscopic simulation tools were used in Dallas[17] and Minneapolis[18] (DIRECT and DynusT, respectively) and a microscopic tool utilized in San Diego[19] (TransModeler). All three models were capable of supporting both trip record generation as well as the analysis of operational conditions. The resulting calculation procedures are documented in this paper. Cambridge Systematics staff coded, tested and utilized the calculation methods consistently in all three sites, and detailed results from these analyses will be released in 2011.

Travel Time

Our basic unit of observation in calculating ICM-related performance measures is a trip i made between an origin o, finishing at a destination d, starting at a particular time τ' using mode m.

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[15] Cambridge Systematics *et al*., Cost-Effective Performance Measures for Travel Time Delay, Variation, and Reliability, NCHRP Report 618, Transportation Research Board, 2008.

[16] Holm P., Tomich, D., Sloboden, J., Lowrance, C., Traffic Analysis Toolbox Volume IV: Guidelines for Applying CORSIM Microsimulation Modeling Software, January 2007, FHWA-HOP-07-079.

[17] Poe, C., Olyai, K., and Abdelghani, K., "Modeling U.S.-75 Integrated Corridor Management in Dallas, Texas" presented at the TRB Integrated Corridor System Management Modeling Best Practices Workshop, Irvine, CA (September 2009).

[18] Chiu, Y., Hickman M., Head, L., Papayannoulis, Y., Kary, B., and Deeter, D., "Minneapolis Integrated Corridor Management Pioneer Site Concept and Strategy Modeling –Part 2: Analysis Modeling and Simulation Innovations" presented at the TRB Integrated Corridor System Management Modeling Best Practices Workshop, Irvine, CA (September 2009).

[19] Estrella, A., ICM Modeling: The Regional Perspective, presented at the TRB Integrated Corridor System Management Modeling Best Practices Workshop, Irvine, CA (September 2009).

We record travel time from a single run of the simulation under operational conditions k for this unit of observation as $t_i^k = t_{o,d,\tau',m}^k$. [20] *Operational conditions* here refer to a specific set of simulation settings reflecting a specific travel demand pattern and collection of incidents derived from a cluster analysis of observed traffic count data and incident data. An example of an operational condition would be an AM peak analysis with 5 percent higher than normal demand and a major arterial incident.

First, for this particular run(s) representing a specific operational condition, we calculate an average travel time for trips between the same o-d pair that begin in a particular time window. Let τ represent this interval, e.g., an interval between 6:30 AM and 6:45 AM and $\mathbf{I}_{o,d,\tau,m}^k$ the set of $n_{o,d,\tau,m}^k$ trips from o to d starting in interval τ under operational condition k using mode m. Note that $\mathbf{I}_{o,d,\tau,m}^k$ is a collection of trips and $n_{o,d,\tau,m}^k$ the scalar value indicating the number of trips contained in $\mathbf{I}_{o,d,\tau,m}^k$.

The classification of travel mode may be determined independently at each site, but the breakdown should capture the combination of all modes utilized in making the trip. For example, one may choose to classify non-HOV-auto trips as a mode separately from non-HOV-auto/HOV/walk trips to track the performance of travelers utilizing park-and-ride facilities. However, any classification of modes must be mutually exclusive and collectively exhaustive, that is, $\bigcup_m \mathbf{I}_{o,d,\tau,m}^k = \mathbf{I}_{o,d,\tau}^k$ and $\sum_m n_{o,d,\tau,m}^k = n_{o,d,\tau}^k$.

The average travel time of trips with origin and destination by mode staring in this time interval is:

$$T_{o,d,\tau,m}^k = \frac{\sum_{i \in \mathbf{I}_{o,d,\tau}^k} t_i^k}{n_{o,d,\tau,m}^k} \qquad \text{(Equation 1)}$$

The calculation of Equation 1 must also include some estimated travel time for trips that cannot reach their destinations by the end of the simulation period. Later in this document, we will discuss the method for estimating travel times for these trips still underway when the simulation ends.

Next, we calculate the average travel time for this same set of trips across all operational conditions. Let k be a specific operational condition and the set of all conditions K. Note that each condition has a probability of occurrence p_k and $\sum_k p_k = 1$. Equation 2 finds the average travel time by mode for all trips from o to d starting in interval τ over all conditions $k \in K$:

$$T_{o,d,\tau,m} = \sum_{k \in K} T_{o,d,\tau,m}^k p_k \qquad \text{(Equation 2)}$$

[20] In the case where multiple random seeds are varied, but the operational conditions are identical, this travel time represents an average for a single trip across the multiple runs. Also, note that this discussion of measures assumes that we are calculating measures for a single case (e.g., pre-ICM); later we will address comparisons between cases.

The average number of trips by mode from o to d starting in interval τ over all conditions $k \in K$:

$$n_{o,d,\tau,m} = \sum_{k \in K} n^{k}_{o,d,\tau,m} p_k \qquad \text{(Equation 2a)}$$

Combining across modes, the average travel time of trips from o to d starting in interval τ under operational condition k:

$$T^{k}_{o,d,\tau} = \frac{\sum_{m} T^{k}_{o,d,\tau,m} n^{k}_{o,d,\tau,m}}{n^{k}_{o,d,\tau}} \qquad \text{(Equation 3)}$$

The average travel time for all trips from o to d starting in interval τ over all conditions $k \in K$:

$$T_{o,d,\tau} = \sum_{k \in K} T^{k}_{o,d,\tau} p_k \qquad \text{(Equation 4)}$$

The average number of trips from o to d starting in interval τ over all conditions $k \in K$:

$$n_{o,d,\tau} = \sum_{k \in K} n^{k}_{o,d,\tau} p_k \qquad \text{(Equation 4a)}$$

Equation 5 defines the trip-weighted average travel time of the system across all o, d, τ:

$$\overline{T} = \frac{\sum_{\forall o,d,\tau} T_{o,d,\tau} n_{o,d,\tau}}{\sum_{\forall o,d,\tau} n_{o,d,\tau}} \qquad \text{(Equation 5)}$$

Delay

Delay can be broadly defined as travel time in excess of some *subjective minimum* travel time threshold. Often, discussions of delay focus solely on roadway-only travel focus on either travel time at posted speeds or 85th percentile speeds. Delay for ICM must be defined differently since ICM explicitly includes multimodal corridor performance. Instead, we directly identify delay at the o, d, m level by deriving a zero-delay threshold, mode $T^{0}_{o,d,\tau,m}$.

This can be derived from travel time outputs over all operational conditions:

$$T^{0}_{o,d,\tau,m} = \min_{k \in K} \left\{ T^{k}_{o,d,\tau,m} \right. \qquad \text{(Equation 6)}$$

In some cases, the cluster analysis will group low-demand, non-incident conditions into a large, high-probability operational condition. In this case, it is possible that a notionally “low” demand pattern will still produce significant congestion in the corridor, particularly in a peak-period analysis.

For this reason, the minimum threshold may also be calculated as the travel time derived in the pre-ICM case under a substantially reduced demand pattern with no incidents or weather impacts. The reduced demand pattern should produce enough trips to generate travel time statistics by mode for every set of trips from o to d starting in interval τ (i.e., $n^0_{o,d,\tau,m} > 0 \ \forall \ o,d,\tau,m$). At the same time, the reduced demand should generate no volume-related congestion in the network.

Alternatively, $T^0_{o,d,\tau,m}$ may be estimated directly from model inputs. For consistency, however, the travel time associated with these thresholds should include expected transfer time between modes and unsaturated signal delay as in the case where a low-demand pattern is used to drive a zero-delay model run.

From our previous calculation of travel time in Equation 1, recall the average travel time of all trips traversing the network from origin o to destination d starting in time interval τ using mode m under operational condition k, $T^k_{o,d,\tau,m}$

Using zero-delay thresholds $T^0_{o,d,\tau,m}$, calculate average trip delay under condition k for each o,d,τ,m:

$$D^k_{o,d,\tau,m} = max\left[T^k_{o,d,\tau,m} - T^0_{o,d,\tau,m}, 0\right] \qquad \text{(Equation 7)}$$

Combining across all operational conditions, calculate the average delay for each o,d,τ,m:

$$D_{o,d,\tau,m} = \sum_{k \in K} D^k_{o,d,\tau,m} p_k \qquad \text{(Equation 7a)}$$

Combining across modes, the average delay for trips from o to d starting in interval τ :

$$D_{o,d,\tau} = \frac{\sum_m D_{o,d,\tau,m} n_{o,d,\tau,m}}{n_{o,d,\tau}} \qquad \text{(Equation 8)}$$

Systemwide average trip delay (Equation 9):

$$D = \frac{\sum_{\forall o,d,\tau} D_{o,d,\tau} n_{o,d,\tau}}{\sum_{\forall o,d,\tau} n_{o,d,\tau}} \qquad \text{(Equation 9)}$$

Aggregating this average delay over all trips produces total system delay (Equation 10):

$$\hat{D} = \sum_{\forall o,d,\tau} D_{o,d,\tau} n_{o,d,\tau} \qquad \text{(Equation 10)}$$

Travel Time Reliability

Corridor reliability measures are inherently measures of outlier travel times experienced by a traveler making the same (or similar) trip over many days and operational conditions. This is convenient given that we have already defined and organized travel time measures from the simulation with respect to trips from o to d starting in interval τ over all conditions $k \in K$. Just as in the case of the subjective notion of delay as travel time in excess of some minimum threshold, the notion of what reliable travel is depends on a *relative maximum* acceptable travel time threshold. For the ICM AMS effort, as in many studies with a travel reliability measure, a threshold based on the 95th percentile travel time is selected. Note that this percentile is calculated considering travel times for similar trips (i.e., o, d, τ) with respect to travel time variation induced by changes in operational conditions $k \in K$.

To identify the 95th percentile travel time, first we generate an ordered list of travel times by o, d, τ:

$$\mathbf{T}_{o,d,\tau} = \left[T^1_{o,d,\tau}, T^2_{o,d,\tau}, \cdots, T^J_{o,d,\tau}\ \right] \text{ where } T^j_{o,d,\tau} \le T^{j+1}_{o,d,\tau} \text{ for all } j = 1 \cdots J. \qquad \text{(Equation 11)}$$

The 95th percentile travel time from this list is identified using the probabilities associated with each operational condition.

$$T^{[95]}_{o,d,\tau} = T^j_{o,d,\tau} \text{ where } \sum_{k=1}^{j} p_k = 0.95. \qquad \text{(Equation 11a)}$$

Note the array of travel times $\mathbf{T}_{o,d,\tau}$ represents levels on a linear step-function. This implies that if 17.4 minutes is the travel time associated with an operational condition occupying the 92nd through 98th travel time percentile, we simply use the 17.4-minute travel time as the 95th percentile value. Also note that the specific operational conditions under which the 95th percentile travel time is found will vary among o, d, τ. For example, a major freeway incident creates congestion and high travel times for trips that originate upstream of the incident location, but creates free-flowing and uncongested conditions for trips that originate downstream of the incident location.

Equation 12 defines planning time index, the ratio of the 95th percentile travel time to the zero-delay travel time for trips from o to d starting in interval τ using mode m over all conditions $k \in K$:

$$\rho_{o,d,\tau} = \frac{T^{[95]}_{o,d,\tau}}{T^0_{o,d,\tau}} \qquad \text{(Equation 12)}$$

Average systemwide planning time index considers all o, d, τ, weighted average by trip volume:

$$\rho = \frac{\sum_{\forall o,d,\tau} \rho_{o,d,\tau}\, n_{o,d,\tau}}{\sum_{\forall o,d,\tau} n_{o,d,\tau}} \qquad \text{(Equation 13)}$$

Variance in Travel Time

Variance in travel time can be calculated in a variety of ways. The key here is that some care must be taken to isolate the specific variation of interest. Additionally, as variance is strongly influenced by outliers, in order to eliminate any potential bias introduced into the variance of travel times resulting from the estimation of a fulfilled travel time for incomplete travelers at the end of the simulation period, the variance calculation should be restricted to completed travelers defined as set $\ddot{\mathbf{I}}^{k}_{o,d,\tau}$ consisting of $\ddot{n}^{k}_{o,d,\tau}$ trips. While the inclusion of the fulfilled incomplete travelers' travel times in the other performance measures may be influenced by the same bias, the nature of the variance calculation magnifies the effects of that potential bias. This effect may be more significant in larger models where the calibration and validation efforts must be focused on the primary corridor or study area.

Given this, the variance in travel time among members of the same origin, destination, and time interval in a single run is:

$$V^{k}_{o,d,\tau} = \frac{\sum_{i \in \ddot{\mathbf{I}}^{k}_{o,d,\tau}} \left(\ddot{t}^{k}_{i} - \ddot{T}^{k}_{o,d,\tau} \right)^{2}}{\ddot{n}^{k}_{o,d,\tau} - 1}$$

(Equation 14)

Recall $K'_{o,d,\tau}$, $K'_{o,d,\tau} \subseteq K$ as the subset of conditions where $\ddot{n}^{k}_{o,d,\tau} > 0$. The variance of travel time for each o, d, τ under all operation conditions is then defined as:

$$V_{o,d,\tau} = \frac{\sum_{k \in K'_{o,d,\tau}} V^{k}_{o,d,\tau} p_k}{\sum_{k \in K'_{o,d,\tau}} p_k}$$

(Equation 14a)

The average variance among all o, d, τ is a weighted average of the variances:

$$V = \frac{\sum_{\forall o,d,\tau} V_{o,d,\tau} \, \ddot{n}_{o,d,\tau}}{\sum_{\forall o,d,\tau} \ddot{n}_{o,d,\tau}}$$

(Equation 14b)

Throughput

The role of a throughput measure in ICM is to capture the primary product of the transportation system: travel. Particularly in peak periods, the capability of the transportation infrastructure to operate at a high level of efficiency is reduced. One of the goals of ICM is to manage the various networks (freeway, arterial, transit) cooperatively to deliver a higher level of realized system capacity in peak periods. While throughput (e.g., vehicles per lane per hour) is a well-established traffic engineering point measure (that is, in a single location), there is no consensus on a system-wide analog measure. In the ICM AMS effort, we use the term *corridor throughput* to describe a class of measures used to characterize the capability of the integrated transportation system to efficiently and effectively transport travelers. We do not consider freight throughput in these calculations, although this could be revisited at a later date. Simple measures of aggregate travel distance cannot differentiate between a well-managed system and a poorly managed system because passenger-trip distances are counted equally regardless of trip duration. In other words, a 5-mile trip completed in 15 minutes counts equally with the same 5-mile trip completed in two hours. In ICM, we are interested in the ability of the integrated multimodal transportation system to deliver trips reliably under peak demand, so two additional measures were defined around the concept of aggregate system-level reliable trip throughput.

In order to support throughput measures, additional trip data need to be generated as simulation outputs. For each trip i made between an origin o, finishing at a destination d, starting at a particular time τ' we obtain from the simulation the travel time $t^k_{o,d,\tau'}$ and a distance traveled $s^k_{o,d,\tau'}$. In some cases, trip-level outputs from the simulation are only available at a vehicle level, so some trips may have multiple passengers associated with that trip (e.g., in the case of carpool travel). Let $x^k_{o,d,\tau'}$ represent the number of travelers associated with a particular trip record.

<u>Reliable Passenger-miles delivered (PMD) and Reliable Passenger-trips delivered (PTD)</u> are measures that combine notions of travel reliability and system throughput. To calculate reliable trip throughput, we specifically identify passenger-miles traveled (or passenger-trips delivered) on trips that successfully complete their trips with travel times below a specified reliability threshold.

First, from the set of pre-ICM case analyses, we identify a set of 95th percentile reliability thresholds from simulation runs associated with analyzing the pre-ICM case. These thresholds are denoted $T^{[95]*}_{o,d,\tau}$.

Let $\dot{\mathbf{I}}^k_{o,d,\tau}$ be the set of trips from o to d starting in interval τ under operational condition k that have travel times equal to or less than the reliability threshold, that is, where $T^k_{o,d,\tau} \le T^{[95]*}_{o,d,\tau}$.

Equation 15 shows passenger-trips delivered (PTD) calculated at the o,d,τ level.

$$Y^k_{o,d,\tau} = \frac{\sum_{i \in \dot{I}^k_{o,d,\tau}} x^k_i}{\dot{n}^k_{o,d,\tau}}$$

(Equation 15)

Equation 16a finds the average PTD for all trips from o to d starting in interval τ over all operational conditions $k \in K$:

$$Y_{o,d,\tau} = \sum_{k \in K} Y^k_{o,d,\tau} p_k$$

(Equation 16a)

Equation 16b defines the aggregate PTD across all o,d,τ:

$$Y = \sum_{\forall o,d,\tau} Y_{o,d,\tau}\, \dot{n}_{o,d,\tau}$$

(Equation 16b)

Passenger-miles delivered (PMD) is a distance-weighted measure of throughput based on PTD:

$$Z^k_{o,d,\tau} = \frac{\sum_{i \in \dot{\mathbf{I}}^k_{o,d,\tau}} s^k_i x^k_i}{\dot{n}^k_{o,d,\tau}}$$

(Equation 17)

Equation 18 finds the average PMD for all trips from o to d starting in interval τ over all operational conditions $k \in K$:

$$Z_{o,d,\tau} = \sum_{k \in K} Z^k_{o,d,\tau} p_k$$

(Equation 18)

Equation 19 defines the aggregate PMD across all o, d, τ :

$$Z = \sum_{\forall o,d,\tau} Z_{o,d,\tau} \, \dot{n}_{o,d,\tau}$$

(Equation 19)

Estimation of Travel Times and Travel Distance for Incomplete Trips

Trips that cannot complete their trips by the time that the simulation ends are still included in the calculation of all delay and travel time calculations. Our approach is to estimate total travel time including any additional time that would be required to complete the trip given the average speed of travel.

First, let $\ddot{\mathbf{I}}^0_{o,d,\tau}$ be the set of $\ddot{n}^0_{o,d,\tau}$ trips from origin o , destination d starting a trip in time interval τ that can be completed under the low-demand operational condition used to identify the zero-delay travel times.

The average distance traveled over these trips is:

$$\ddot{X}^0_{o,d,\tau} = \frac{\sum_{i \in \ddot{\mathbf{I}}^0_{o,d,\tau}} s_i}{\ddot{n}^0_{o,d,\tau}}$$

(Equation 20)

Note: If $\ddot{n}^0_{o,d,\tau} = 0$ then $\ddot{X}^0_{o,d,\tau}$ is indeterminate. In this case, find τ' , the closest time interval such that $\tau' < \tau$ AND $n^0_{o,d,\tau'} > 0$. Approximate $\ddot{X}^0_{o,d,\tau}$ using $\ddot{X}^0_{o,d,\tau'}$.

Next, let $\overleftarrow{\mathbf{I}}^k_{o,d,\tau}$ be the set trips from origin o , destination d starting a trip in time interval τ that *cannot* be completed under operational condition k . For all $i \in \overleftarrow{\mathbf{I}}^k_{o,d,\tau}$, let $\overleftarrow{x}^k_i$ be the distance traveled on the trip i up to the point where the simulation ends, and let $\overleftarrow{t}^k_i$ the travel time on trip i up to the point where the simulation ends. Average travel speed for a trip that cannot be completed is expressed in Equation 21:

$$\overleftarrow{v}^k_i = \frac{\overleftarrow{x}^k_i}{\overleftarrow{t}^k_i}$$

(Equation 21)

Estimated total trip travel time for a trip that cannot be completed before the simulation ends is the accumulated travel time plus the time to travel the remaining distance at average trip speed:

$$t_i^k = \overleftarrow{t}_i^k + max\left\{ \frac{\left(\ddot{X}_{o,d,\tau}^0 - \overleftarrow{x}_i^k \right)}{\overleftarrow{v}_i^k}, 0 \right\} \qquad \text{(Equation 22)}$$

$$x_i^k = max\left\{ \ddot{X}_{o,d,\tau}^0, \overleftarrow{x}_i^k \right\} \qquad \text{(Equation 23)}$$

Comparing Pre-ICM and Post-ICM Cases

All of the travel time and throughput measure calculation procedures defined above are conducted under a single set of simulation settings reflecting a specific set of corridor management policies, technologies and strategies (often called an *alternative*). The complete suite of delay, travel time reliability and throughput measures are calculated independently for each case (e.g., Pre-ICM and Post-ICM). Comparisons of the resulting measures are then made to characterize corridor performance under each case. Only in the case of measures of reliable corridor throughput is post-ICM alternatives considered directly in comparison to travel time thresholds identified in the pre-ICM case.

Comparing Observed and Simulated Performance Measures

These few key measures have been defined in detail for national consistency across all AMS sites. Sites have also identified measures. This document has dealt in detail with the calculation of measures from simulation outputs. However, the calculation of comparable measures using observed data demands an equivalent level of detailed attention. These observed measures will be critical in the AMS effort to validate modeling accuracy and in performance measurement in the demonstration phase. Because of the nature of the simulation output, the modeling analyst is able to resolve and track performance at a level of detail that is not available to an analyst working with field counts, speeds and transit passenger-counter outputs. However, it is the responsibility of the site and the AMS contractor to ensure that these measures are similar in intent, if not in precise calculation. In many cases, the simulation tools or their basic outputs can be manipulated to produce measures directly comparable with field data. An example of this is in throughput calculation, where a site may wish to pursue a screenline passenger throughput measure from field data. In addition to the system-level throughput measures detailed above, the simulation model can be configured to produce passenger-weighted counts across the same screenline to match the field throughput measure.

Colleagues who have contributed substantively to this document either conceptually or by identifying needed corrections and clarifications include:

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APPENDIX B. Data Collection Plan

B.1 Introduction and Background

The objective of the ICM initiative is to demonstrate how 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 an estimated 300 corridors in the country with under-utilized capacity (in the form of parallel transit capacity (bus, rail, BRT, etc.) and/or arterials and under-utilized travel lanes) that could benefit from ICM.

The maturation of ITS technologies, availability of supporting data, and emerging multiagency institutional frameworks make ICM practical and feasible. There are a large number of freeway, arterial, and transit optimization strategies available today and in widespread use across the U.S. Most of these strategies are managed locally by individual agencies on an asset-by-asset basis. Even those managed regionally are often managed in a stove-piped manner (asset-by-asset) rather than in an "integrated" fashion across a transportation corridor. Dynamically applying these strategies in combination across a corridor in response to varying conditions is expected to reduce congestion "hot spots" in the system and improve the overall productivity of the system. Furthermore, providing travelers with actionable information on alternatives (such as mode shift, time of travel shift, and/or route shift) is expected to mitigate bottlenecks, reduce congestion, and empower travelers to make more informed travel choices.

We currently are in Stage 2 of the ICM Initiative, where the primary objective is to conduct AMS for three Stage 2 ICM Pioneer Sites by developing a modeling platform to evaluate different proposed ICM strategies for each of the three Pioneer Sites. This will help identify cost-effective ICM strategies, and help prioritize ICM investments based on expected performance.

Thus far in Stage 2 for the San Diego I-15 ICM, an analysis plan has been developed, which has outlined the various tasks associated with the application of the ICM AMS tools and strategies for the I-15 Corridor in support of a benefit-cost assessment for the successful implementation of ICM. A major component of the analysis plan is data collection, which can include input data for AMS, performance data for model calibration and validation, and data for ICM Approaches and Strategies.

This ***AMS Data Collection Plan for the I-15 Pioneer Corridor*** outlines the various tasks associated with identifying the data that needs to be collected for application of the ICM AMS tools and strategies to this corridor in order to support benefit-cost assessment for the successful implementation of ICM.

Principles in Developing and Executing the Data Collection Plan

A number of principles apply in developing and executing the data collection plan. These are summarized as follows:

Resource and Timeframe Constraint – The overall ICM AMS effort must take place within the budget and timeframe specified in the analysis plan. In particular, available data at the San Diego Pioneer Site will be leveraged in the AMS effort.

Recognize Current Limitations in Available Data – There are known gaps in the available data that must be bridged by collecting additional field data and deriving estimates for other missing data.

Collate Information on Current and Future Traffic Management Systems – The data collection plan also includes a listing of the resources used by the AMS team to obtain information about current and future (planned) systems that will be replicated in the AMS effort. These systems include hardware components, operational characteristics, and creation and modification attributes, which will be summarized to the extent possible by the AMS team. Any significant assumptions that would be required as a result of absence of any such information will be provided in the Analysis plan.

Correlation between Data Collection for Model Calibration and 2003 Baseline Year – 2003 is the base year selected for analysis since it is the most appropriate time period when there was no significant construction activity happening along the I-15 corridor and for which there is a validated travel demand model. A significant portion of the data collected is for purposes of model calibration and validation for this baseline year.

I-15 Corridor Site and Description

The Pioneer Site identified for this analysis is the Interstate 15 corridor in San Diego, California. The corridor extends from the interchange with SR 163 in the south to the interchange with SR 78 in the north, a freeway stretch of approximately 20 miles. Also included in the study area are the roadways discussed below.

This appendix outlines the AMS Data Collection plan for the I-15 ICM Corridor in San Diego County. The focus of this appendix is on the specific types of data that currently are available, whether in electronic or paper form, including listings of signalized arterial intersections with signal timing plans, volume of through traffic, turning movements, and speeds. In addition, it identifies the gaps in the data where additional data collection is required for the analysis, modeling, and simulation tasks.

The I-15 Corridor Site extends from the interchange with SR 163 in the south to the interchange with SR 78 in the north, a freeway stretch of 21 miles. Also included in the study area are the following seven primary arterial roadways:

- Centre City Parkway;
- Pomerado Road;
- Rancho Bernardo Road;
- Camino Del Norte Road;
- Ted Williams Parkway;

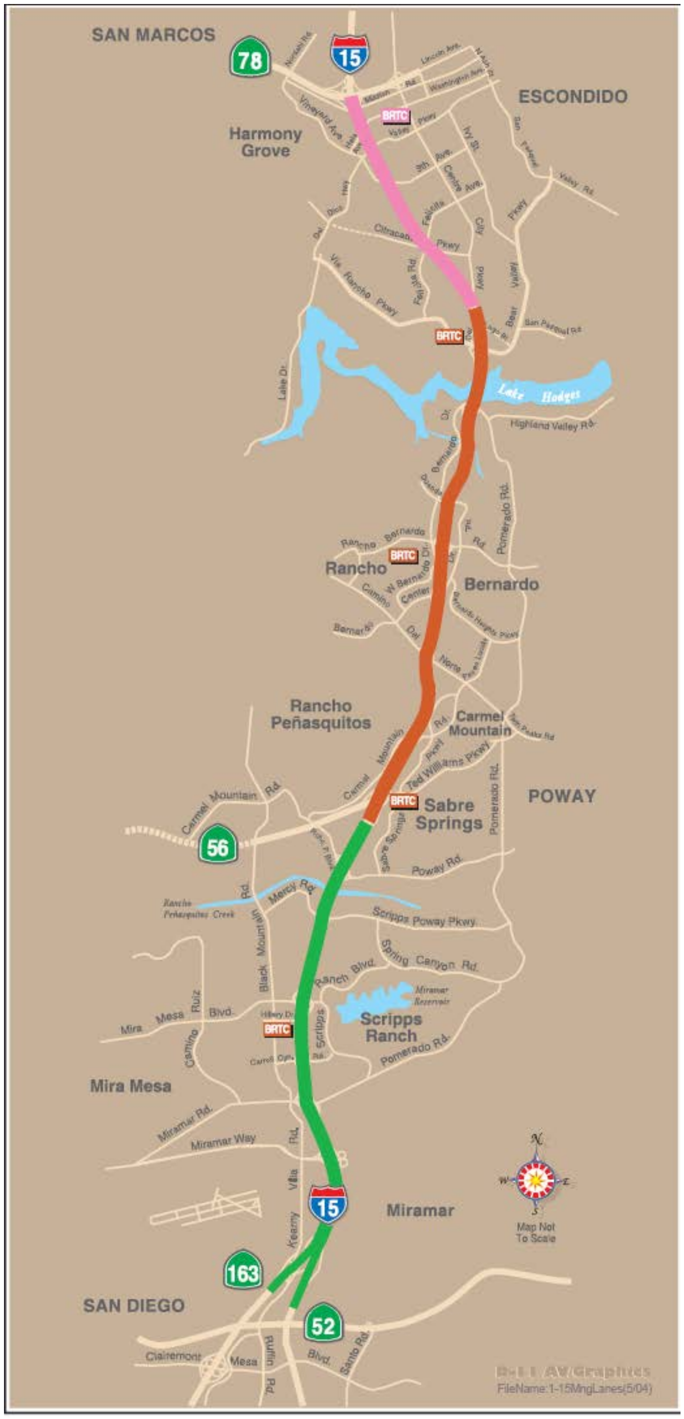
- Black Mountain Road; and
- Scripps Parkway/Mercy Road.

Figure B-1 illustrates the study area and its roadways that will be utilized for analysis of this Pioneer Site. I-15 is divided into three sections (pink, orange, and green) corresponding to the three separate roadway sections under construction as part of the new Managed Lanes with Congestion Pricing facility.

I-15 is an 8- to 10-lane freeway section in San Diego providing an important connection between San Diego and cities such as Poway and Escondido, and destinations to the northeast. The current operations on I-15 include two center-median lanes that run along eight miles of I-15 between SR 163 in south and Ted William Parkway (SR 56) in the north. These center-median lanes are reversible HOV lanes that operate in the southbound direction in the a.m. peak period and in the northbound direction during the p.m. peak period. The current operations also allow SOV to utilize the roadway for a price, effectively operating as HOT lanes. The section between SR 78 and SR 163 (study area) will eventually include four center median lanes, which will have three lanes operating as HOT lanes in the peak direction.

According to the CONOPS report for this corridor, current weekday traffic volumes range from 170,000 to 290,000 vehicles on the general purpose lanes of I-15, and approximately 20,000 vehicles use the I-15 Express Lanes during weekdays. The I-15 corridor is one of three primary north-south transportation corridors in San Diego County, and is the primary north-south highway in inland San Diego County, serving local, regional, and interregional travel. The corridor is a heavily utilized regional commuter route, connecting communities in northern San Diego County with major regional employment centers. The corridor is situated within a major interregional goods movement corridor, connecting Mexico with Riverside and San Bernardino counties, as well as Las Vegas, Nevada.

Figure B-1. Study Area



[Source: SANDAG: AV Graphics, 2008.]

Methodology for Developing the Data Collection Plan

The methodology for developing the data collection plan comprises a four-step process described as follows:

Review all relevant and appropriate I-15 ICM reports and documentation that deal with the I-15 ICM data collection effort in general and specifically about information regarding current and planned transportation management systems. The following resource list has been reviewed:

- Integrated Corridor Management – Analysis, Modeling, and Simulation *Sample Data List* draft report, December 2006;
- Integrated Corridor Management – Analysis, Modeling, and Simulation for the San Diego I-15 in San Diego, California Analysis Plan, November 2008;
- San Diego I-15 Integrated Corridor Management (ICM) System, *Final I-15 ICM Concept of Operations*, March 2008; and
- San Diego I-15 Integrated Corridor Management (ICM), *Final I-15 ICM System Requirements,* March 2008.

Assess the current state of required data by corridor agency stakeholders, including the following:

- SANDAG;
- Caltrans;
- Cities of San Diego, Escondido, and Poway; and
- Metropolitan Transit System and North County Transit District.

Identify gaps between data requirements and available data.

Develop a specific timeline timeframe with which to execute the data collection.

Documentation Review

The purpose of the *Sample Data List* memorandum is to provide a sample data list for the AMS work to be conducted, which includes the following:

- Input data for AMS;
- Performance data for model calibration and validation; and
- Data for ICM Approaches and Strategies.

Input data for AMS is organized into the following components:

- Network;
- Travel Demand;
- Traffic Control;

- Transit; and
- ITS elements.

Table B-1 below provides a summary of the input data required for AMS. The Sample Data List memorandum provides a full description of each of these input data components.

Performance data for model calibration and validation is based on a three-step framework for microscopic models that is described in the Sample Data List. The framework suggests that the following data are important for model calibration and performance analysis:

- Capacity at bottleneck locations;
- Traffic volumes at key network locations;
- Travel times on network links; and
- Spatial and temporal extent of queuing.

Table B-2 shows the Data Requirements for the San Diego I-15 ICM Approaches and Strategies based on work performed in the development of the analysis plan, which in turn, was formulated from the CONOPS. The table is configured as a matrix with ICM Approaches and Strategies, together with the AMS Input Data components.

Table B-3 maps the data shown per category in Table B-2 with the ICM Approaches and Strategies to produce the sample data list for each ICM strategy.

Table B-1. Input Data for AMS

Network	Travel Demand	Traffic Control	Transit	ITS Elements
Link Distances	Link Volume	Freeways	Transit Routes	Surveillance System
Free-flow Speeds	Traffic Composition	Ramp Metering	Transit Stops	*Detector Type*
Geometrics – Freeways	On- and Off-Ramp Volumes	*Type (local, system-wide)*	Location	*Detector Spacing*
# Travel Lanes	Turning Movement Counts	*Detectors*	Geometrics	*CCTV*
Presence of Shoulders	Vehicle Trip Tables	*Metering Rates*	Dwell Times	Information Dissemination
# HOV Lanes (if any)	Person Trip Tables	*Algorithms (adaptive metering)*	Transit Schedules	*CMS*
Operation of HOV Lanes	Transit Ridership	Mainline Control	Schedule Adherence Data	*HAR*
Accel/Dec Lanes		*Metering*	Transfer Locations	*Other (e.g., 511)*
Grade		*Lane Use Signals*	Transit Speeds	*In-vehicle Systems*
Curvature		*Variable Speed Limits*	Transit Fares	Incident Management
Ramps		Arterials	*Payment Mechanisms*	*Incident Detection*
Geometrics – Arterials		Signal System Description	Paratransit	*CAD System*
Number of Lanes		*Controller Type*	*Demand-responsive*	*Response and Clearance*

Network	Travel Demand	Traffic Control	Transit	ITS Elements
Lane Usage		*Phasing*	*Rideshare programs*	*Incident Data Logs*
Length of Turn Pockets		*Detector Type and Placement*		Tolling System
Grade		*Signal Settings*		*Type*
Turning Restrictions		Signal Timing Plans		*Pricing Mechanisms*
Parking		Transit Signal Priority System		TMC
Parking Facilities		*Control Logic*		*Control Software/Functions*
Location		*Detection*		*Communications*
Capacity		*Settings*		*Data Archival Dissemination*
Park and Ride Lots		Emergency Preemption System		Transit/Fleet Management System
Location		*Control Logic*		*AVL*
Capacity		*Detection*		*Communications*
		Settings		*Traveler Information Bus Stops*
	These data must be provided for all links in the corridor study area.			
	These data must be provided for a consistent analysis time period, including the same date for data from all facilities in the corridor area.			
	To facilitate the assessment of variability in traffic volumes and speeds, data must be provided for multiple days of the week and months of the year for all facilities in the study corridor.			

[Source: *Sample Data List*, December 2006.]

Table B-2. Data Requirements for San Diego I-15 ICM Approaches and Strategies

	Data Requirements				
ICM Approaches and Strategies	Network Data	Demand	Control	Transit	ITS Elements
ATIS pre-trip information	X	X			X
ATIS en-route traveller information	X	X			X
Signal priority to transit	X	X	X	X	X
Coordinated operation ramp meters and arterial traffic signals	X		X		X
Physical Bus Priority			X	X	
Modify ramp metering rates to accommodate traffic shifting from arterial		X	X		
Modify HOV restrictions	X	X		X	
Congestion pricing on Managed Lanes		X			

[Source: *Sample Data List*, December 2006.]

Table B-3. Data List for San Diego I-15 ICM Approaches and Strategies

ICM Approaches and Strategies	Data Requirements				
	Network Data	Demand	Control	Transit	ITS Elements
ATIS pre-trip information	Link distances, geometrics	Link volumes			
ATIS en-route traveller information	Link distances, geometrics	Link volumes			
Signal priority to transit	Link distances, free-flow speeds, geometrics (arterials)	Link volumes, turning movement counts, transit ridership	Arterial signal timing plans, transit signal priority system, QuicNet 4+ system	Transit routes, stops, schedules, schedule adherence data, speeds	
Coordinated operation ramp meters and arterial traffic signals	Link distances, free-flow speeds, geometrics		Freeway ramp metering, arterial signal timing plans, QuicNet 4+ system		
Physical Bus Priority					
Modify ramp metering rates to accommodate traffic shifting from arterial	Link volumes, on-ramp volumes, turning movement counts		Freeway ramp metering		
Modify HOV restrictions	Geometrics (freeway)			Paratransit, transit routes	
Congestion pricing on Managed Lanes					

[Source: *Sample Data List*, December 2006.]

The *Concept of Operations and System Requirements* documents provide information on the I-15 ICM System currently including existing and planned-for systems together with a timeline for their implementation. Of particular relevance to and importance for the data collection plan are the Intermodal Transportation Management System (IMTMS) and the Decision Support System (DSS). The IMTMS system is an existing data acquisition and dissemination network within the San Diego region; it is, in turn, connected to a number of existing and planned external systems in the region including, but not limited to, the Regional Arterial Management System (RAMS), the Regional Transit Management System (RTMS), and the ATMS 2005. Since these systems will be replicated in the course of the AMS effort, the team is collecting data/information about such systems as they relate to the selected ICM strategies and application scenarios.

Current State of Required Data and Gap Identification

The current state of required data varies by individual network: arterial, freeway, and transit. Each is presented in separate sections of this appendix.

Arterial-Related Data

Table B-4 below provides a summary of the data available along the seven arterials included in the study area. Data requested or obtained for these arterials includes the following:

- Signal timings;

- Vehicle through volumes;
- Turning movement counts; and
- Pedestrian volumes.

Where data is present, cells are either marked with a “Y” (for yes, data available) or with the year data is available. Empty cells indicate locations where data currently is unavailable. In addition, cells marked with “NA” under the signal timing plans column indicate that these intersections are unsignalized. Any missing signal timing plans have been requested from both Caltrans and local government agencies. Acquiring vehicle turning movement counts, on the other hand, will be subcontracted to a data collection firm for all 107 intersections as there appears to be a significant gap in the availability of traffic count information along the arterials. Turning movement counts will be conducted on typical weekdays (Tuesday, Wednesday, and Thursday) during the a.m. peak period between the hours of 5:00 a.m. and 10:00 a.m. Counts will be conducted preferably within a similar timeframe window (a minimum two weeks).

Table B-4. Arterials Data Availability and Gaps

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
1	Black Mountain Road at Activity Road	Y	2001	2001	2001	Y
2	Black Mountain Road at Canyonside Park	Y				Y
3	Black Mountain Road at Capricorn Way	Y	2003	2003	2003	Y
4	Black Mountain Road at Carmel Mountain Road	Y	2002	2002	2002	Y
5	Black Mountain Road Carmel Valley Road					Y
6	Black Mountain Road Carroll Canyon Road	Y				Y
7	Black Mountain Road Carroll Center Road	Y	2002	2002	2002	Y
8	Black Mountain Road at Emden Road	N/A	2002	2002	2002	Y
9	Black Mountain Road Galvin Avenue	Y	2003	2003	2003	Y
10	Black Mountain Road at Gemini Avenue	Y	2003	2003	2003	Y
11	Black Mountain Road at Gold Coast Drive	Y				Y
12	Black Mountain Road at Hillery Drive	Y	2003	2003	2003	Y
13	Black Mountain Road at Maler Road					Y
14	Black Mountain Road at Maya Linda Drive	Y				Y
15	Black Mountain Road at Miramar College entrance	Y	2003	2003	2003	Y
16	Black Mountain Road at Miramar Road	Y	2000	2000	2000	Y
17	Black Mountain Road at Mercy Road	Y				Y
18	Black Mountain Road at Mira Mesa Boulevard	Y	2003	2003	2003	Y
19	Black Mountain Road at Montalban	Y				Y

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
20	Black Mountain Road at Oviedo Street	Y				Y
21	Black Mountain Road at Park Village Road	Y				Y
22	Black Mountain Road at Stargaze Avenue	Y				Y
23	Black Mountain Road at Twin Trails Drive	Y				Y
24	Black Mountain Road at Westview Parkway	Y				Y
25	Camino Del Norte at Carmel Mountain Road	Y				Y
26	Camino Del Norte at Paseo Montanoso					Y
27	Camino Del Norte at World Trade Drive	Y				Y
28	Centre City at 13th	Y				Y
29	Centre City at 9th	Y				Y
30	Centre City at Citracado	Y	2007, 2004	2004	2007, 2004	Y
31	Centre City at (Felicita) Town Centre Dr./W. 18th Av.	Y				Y
32	Centre City at Decatur Way	Y		2005		Y
33	Centre City at El Norte	Y	2005		2005	Y
34	Centre City at Felicita	Y	2003			Y
35	Centre City at Grand	Y	2005	2005	2005	Y
36	Centre City at Mission	Y	2005		2005	Y
37	Centre City at Washington	Y	2001, 2005	2001, 2005	2001, 2005	Y
38	Centre City NB Loop Off to SR 78	N/A				Y
39	Centre City Parkway at Country Club Lane	Y	2005	2005	2005	Y
40	Centre City Parkway at 5th Avenue	Y	2003			Y
41	Centre City Parkway at Iris	Y				Y
42	Centre City Parkway at Valley Parkway	Y	2005, 2004	2005	2004, 2005	Y
43	Centre City Parkway at W. 2nd Avenue	Y	2002, 2005	2005	2002, 2005	Y
44	Centre City Parkway at SB Off to SR 78	N/A				Y
45	Centre City SB On from SR 78	N/A				Y
46	Centre City at NB Loop On from SR 78	N/A				Y
47	Pomerado Road at 9th	Y				Y
48	Pomerado Road at Avenida La Valencia/ Higa Place	Y	2005	2005	2005	Y
49	Pomerado Road at Avenida Magnifica	Y	2003	2003	2003	Y
50	Pomerado Road at Bernardo Heights Parkway	Y				Y
51	Pomerado Road at Casa Avenida	Y				Y

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
52	Pomerado Road at Chabad Center Driveway	Y				Y
53	Pomerado Road at Colony Drive	Y				Y
54	Pomerado Road at Cypress Canyon Road	Y				Y
55	Pomerado Road at Escala Drive	Y	2005	2005	2005	Y
56	Pomerado Road at Fairbrook Road	Y				Y
57	Pomerado Road at Fire Station Road	Y				Y
58	Pomerado Road at Glen Oak Road	Y				Y
59	Pomerado Road at Greens East Rd/Paseo Del Verano	Y	2005	2005	2005	Y
60	Pomerado Road at Highland Valley Road/Paseo Monte Batalla	Y				Y
61	Pomerado Road at Legacy Road	Y	2004	2004	2004	Y
62	Pomerado Road at Meadowbrook Lane	Y				Y
63	Pomerado Road at Metate Lane	Y				Y
64	Pomerado Road at Mirasol Drive	Y	2005	2005	2005	Y
65	Pomerado Road at Monte Vista	Y				Y
66	Pomerado Road at Oak Knoll	Y				Y
67	Pomerado Road at Oaks North Drive	Y	2005	2005	2005	Y
68	Pomerado Road at Old Pomerado	Y				Y
69	Pomerado Road at Paseo del Verano Norte	Y	2005	2005	2005	Y
70	Pomerado Road at Pomerado Hospital	Y				Y
71	Pomerado Road at Poway	Y				Y
72	Pomerado Road at Rancho Bernardo Road	Y				Y
73	Pomerado Road at Rios Road	Y	2005	2005	2005	Y
74	Pomerado Road at Robison	Y				Y
75	Pomerado Road at Scripps Poway	Y				Y
76	Pomerado Road at Scripps Ranch Boulevard	Y				Y
77	Pomerado Road at Semillon Boulevard	Y				Y
78	Pomerado Road at Stone Canyon Road	Y	2005	2005	2005	Y
79	Pomerado Road at Stonebridge Parkway	Y				Y
80	Pomerado Road at Stowe	Y				Y
81	Pomerado Road at Ted Williams Parkway	Y				Y
82	Pomerado Road at Treadwell	Y				Y

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
83	Pomerado Road at Twin Peaks/Camino Del Norte	Y				Y
84	Pomerado Road at Willow Creek Road	Y				Y
85	Rancho Bernardo Road at Acena Drive					Y
86	Rancho Bernardo Road at Bernardo Center Drive					Y
87	Rancho Bernardo Road at Bernardo Oaks Drive					Y
88	Rancho Bernardo Road at Matinal Road					Y
89	Rancho Bernardo Road at Via Del Campo					Y
90	Rancho Bernardo Road at West Bernardo Drive					Y
91	Scripps at Scripps Highlands Drive					Y
92	Scripps Poway at Scripps Creek					Y
93	Scripps Poway at Scripps Summit Drive					Y
94	Scripps Poway at Spring Canyon Road					Y
95	Scripps Poway at Springbrook Drive					Y
96	Scripps Poway at Village Ridge/Cypress Canyon Road					Y
97	Mercy at Alemania Road					Y
98	SR 56 at Black Mountain Road	Y				Y
99	SR 56 at Highland Ranch Road	Y				Y
100	SR 56 EB at Rancho Carmel Drive	Y				Y
101	SR 56 loop off and diag on ramps at Rancho Penasquitos	Y				Y
102	SR 56 loop on and diag off at Rancho Penasquitos	Y				Y
103	SR 56 WB at Black Mountain Road	Y				Y
104	SR 56 WB at Rancho Carmel Drive	Y				Y
105	Ted Williams Parkway at Esprit Av/Highland Ranch Road	Y				Y
106	Ted Williams Parkway at Rancho Carmel Drive	Y				Y
107	Ted Williams Parkway at Shoal Creek Drive	Y				Y

B.2 Freeway-Related Data

Caltrans' PeMS web site is capable of providing freeway data as fine as 30-second intervals. PeMS data is collected and archived 24/7 for all operating loop detectors on the freeway system, and the data obtained from it can be aggregated to any time interval: http://pems.eecs.berkeley.edu/. The availability of PeMS data for I-15 is shown in Tables B-5 and B-6 below.

In addition to PeMS data, the following freeway-related information also is available from Caltrans and other public agencies:

- CHP CAD logs are available for freeway incidents, which provides data including date, time, location, lane number, incident type, incident impact (e.g., lane closure, traffic backup);
- Caltrans' Advanced Transportation Management System (ATMS 2005) contains the following data:
  - Freeway congestion;
  - Freeway incidents;
  - Travel times;
  - Planned events;
  - CMS status and current messages;
  - CCTV imagery;
  - Coverage of VDS along I-15 (location and loop status); and
  - Snapshots of freeway loops.
- Freeway ramp metering rates include the following:
- Cycles/minute;
- Vehicles/cycle;
- Vehicles/hour/lane;
- Seconds/cycle;
- Vehicles per hour, and
- Occupancy.

A request has been made to obtain this data for a set of 62 I-15 ramps (both NB and SB).

- Caltrans signal phasing/timing plans at on- and off-ramps to I-15 freeway;
- ITS operations along I-15 freeway, including traffic control systems (signal systems, emergency preemption, and ramp metering) and ITS elements (surveillance systems, information dissemination, incident management, and TMC); and
- Speed Limit information for Baseline Year (2003) on I-15 and primary arterials: AMS Team has received a GIS layer from Caltrans D11 regarding this data.

Table B-5. I-15 Northbound PeMS Data

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
1	I-15 ML	15 NB to HOV	FWY TO FWY		Y
2	I-15 ML at SR 163	I-15 NB HOV On from SR 163	FWY TO FWY		Y
3	SR 163	I-15 NB at SR 163	FWY TO FWY		Y
4	Miramar Way Collector Distributor	Mainline	MANUAL	Y	Y
		15 NB Off to Miramar CD	TMC		Y
		Loop on from Miramar Way CD			
		Loop Off to Miramar Way CD			
		I-15 NB On from Miramar CD		Y	Y
5	Miramar/Pomerado Road	Mainline	MANUAL		
		Miramar/Pomerado Rd at I-15 NB Diag Off and On Ramps	TMC	Y	Y
		I-15 NB Loop On from Pomerado Road		Y	Y
6	Caroll Canyon Road	Mainline	MANUAL	Y	Y
		I-15 NB on and off ramp at Carroll Canyon Road	TMC	Y (only for On)	Y
7	Mira Mesa Boulevard	Mainline	MANUAL	Y	Y
		I-15 NB Diag On from Mira Mesa Boulevard	TMC	Y	Y
		I-15 NB Diag Off to and Loop On from Mira Mesa Boulevard		Y	Y
8	Scripps Poway Parkway/Mercy Road	Mainline	MANUAL	Y	Y
		I-15 NB On and Off ramps at Scripps Poway	TMC	Y (only for On)	Y (only for On)
9	Rancho Penasquitos/Poway Road	Mainline	MANUAL	Y	Y
		I-15 NB Diag Off at Rancho Penasquitos	TMC		Y
		I-15 NB Loop On from Rancho Penasquitos Boulevard		Y	Y

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
		I-15 NB Diag On from Ranchos Penasquitos			
10	SR 56	Mainline	MANUAL		Y
		I-15 NB Off to SR 56	FWY TO FWY		
		I-15 HOV Off to SR 56			Y
		I-15 Loop On from SR 56			Y
		I-15 Diag On from SR 56		Y	Y
11	Carmel Mountain Road	Mainline	MANUAL	Y	Y
		I-15 NB On and Off Ramp at Carmel Mountain Road	TMC	Y	Y
12	Camino Del Norte	Mainline	MANUAL	Y	Y
		I-15 NB On and Off Ramps at Camino Del Norte	TMC	Y(only for ON)	Y(only for ON)
13	Bernardo Center Drive	Mainline	MANUAL	Y	Y
		I-15 NB On and Off Ramp at Bernardo Center Drive	TMC	Y	Y
14	Rancho Bernardo Road	Mainline	MANUAL	Y	Y
		I-15 NB Diag Off to Rancho Bernardo Road	TMC	Y	Y
		I-15 NB Loop On from Rancho Bernardo Road		Y	Y
		I-15 NB Diag On from Rancho Bernardo Road		Y	Y
15	Pomerado Rd/West Bernardo Drive	Mainline	MANUAL	Y	Y
		I-15 NB Loop On from and Diag Off to Pomerado Road	TMC		
16	Via Rancho Parkway	Mainline	MANUAL	Y	Y
		I-15 NB On and Off Ramps at Via Rancho Parkway	TMC	Y(only for ON)	Y(only for ON)
17	S. Centre City Parkway	I-15 NB Off S Centre City Parkway	TMC		
18	Citracado Parkway	Mainline	MANUAL	Y	Y
		I-15 NB Diag Off and On at Citracado Parkway	TMC	Y (only for On)	Y
19	Auto Parkway/9th Avenue	Mainline	MANUAL	Y	Y

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
		I-15 NB Diag Off and On Auto Parkway/9th Avenue	TMC	Y (only for On)	Y
20	West Valley Parkway	Mainline	MANUAL	Y	Y
		I-15 NB Diag On and Off at West Valley Parkway	TMC		
21	SR 78	I-15 NB Loop On from SR 78EB	FWY TO FWY		
		I-15 Off to SR 78			
		I-15 NB On from SR 78 WB			
22	Centre City Parkway	I-15 at Centre City Parkway	ATR OR MANUAL		Y

Table B-6. I-15 Southbound PeMS Data

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
1	I-15 ML	I-15 SB to HOV	FWY TO FWY		Y
2	I-15 ML at SR 163	I-15 SB HOV Off to SR 163	FWY TO FWY		Y
3	SR 163	I-15 SB at SR 163	FWY TO FWY		Y
4	Miramar Way	Mainline	MANUAL	Y	Y
		I-15 SB On from Miramar Way	TMC	Y	Y
		I-15 SB Off to Miramar Road			Y
5	Pomerado Road	Mainline	MANUAL	Y	Y
		I-15 SB Diag On and Off Ramps at Pomerado Road	TMC	Y	Y
		I-15 Diag On from Pomerado Road		Y	Y
6	Caroll Canyon Road	Mainline	MANUAL	Y	Y
		I-15 SB On and Off Ramps at Carroll Canyon Road	TMC	Y	Y
7	Mira Mesa Boulevard	Mainline	MANUAL	Y	Y
		I-15 SB Diag On from Mira Mesa Boulevard	TMC	Y	Y
		I-15 SB Diag and Loop Off to Mira Mesa Boulevard		Y	Y
8	Scripps Poway Parkway	Mainline	MANUAL	Y	Y
		I-15 SB On and Off Ramps at Mercy/Scripps Poway	TMC	Y (only for ON)	Y (only for ON)
9	Rancho Penasquitos	Mainline	MANUAL	Y	Y
		I-15 SB Diag Off to and Loop On from Rancho Penasquitos	TMC	Y (only for ON)	Y (only for ON)
		I-15 SB Diag On from Rancho Penasquitos		Y	Y

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
10	SR 56	Mainline	MANUAL	Y	Y
		I-15 HOV Lanes SB On from SR 56	FWY TO FWY		Y
		I-15 SB On from SR 56			
		I-15 SB Loop On from SR 56			
		I-15 SB Off to SR 56			
11	Carmel Mountain Road	Mainline	MANUAL	Y	Y
		I-15 SB at Carmel Mountain Road	TMC	Y	Y
12	Camino Del Norte				
		I-15 SB at Camino Del Norte	TMC	Y	Y
13	Bernardo Center Drive	Mainline	MANUAL	Y	Y
		I-15 SB On and Off Ramp at Bernardo Center Drive	TMC	Y (only for ON)	Y (only for ON)
14	Rancho Bernardo Road				
		I-15 SB On from Rancho Bernardo Road	TMC	Y	Y
		I-15 SB Loop On from Rancho Bernardo Road		Y	Y
		I-15 Diag Off to Rancho Bernardo Road			
15	Pomerado Rd/West Bernardo Drive				
		I-15 SB Diag On from and Loop Off to Pomerado Rd/W Bernardo Drive	TMC	Y	Y
16	Via Rancho Parkway				
		I-15 SB Diag On and Loop Off to Via Rancho Parkway	TMC	Y	Y
17	Centre City Parkway	Mainline	MANUAL	Y	Y
		I-15 SB On from S Centre City Parkway	TMC	Y	Y
18	Citracado Parkway				
		I-15 SB Diag On from Citracado Parkway	TMC	Y	Y
		I-15 SB Off to Gamble Lane/ Citracado Parkway		Y	Y

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
19	Auto Parkway/9th Avenue	Mainline	MANUAL	Y	Y
		I-15 SB Diag On and Off at Auto Park Way	TMC	Y	Y
20	West Valley Parkway	Mainline	MANUAL	Y	Y
		I-15 SB Diag Off to and Loop On from W Valley Parkway	TMC	Y	Y
21	SR 78	I-15 SB Off to SR 78	FWY TO FWY		
		I-15 SB Loop On from SR 78			
		I-15 SB On from SR 78 EB			
22	Centre City Parkway	I-15 at Centre City Parkway	ATR OR MANUAL		

B.3 Transit-Related Data

In addition to data along freeways and arterials, the availability of transit-related information along the Corridor also has been assessed. The I-15 Corridor is primarily serviced by the following six bus routes:

- Premium Express Bus Route 810 – Escondido to Downtown San Diego;
- Premium Express Bus Route 820 – Poway to Downtown;
- Premium Express Bus Route 850 – Rancho Peñasquitos to Downtown;
- Premium Express Bus Route 860 – Rancho Bernardo to Downtown;
- Express Service Bus Route 20 – Downtown San Diego to North County Fair; and
- Express Service Bus Route 210 – Mira Mesa to Downtown San Diego.

Bus schedules and route information are available through the local transit agency, San Diego Metropolitan Transit System (MTS). We currently are collecting the following transit-related data from MTS and SANDAG; data collection is scheduled for completion in December 2008:

- For the 800 series and Routes 20 and 210 MTS bus routes, we have the following:
  - Passenger survey data between 1995 and 2008.
- For the two express service Routes 20 and 210, we have the following:
  - AVL data (schedule adherence) as far back as 2007; and
  - APC data as far back as 2006.
- We have from multiple databases of incident data (accident logs, incident logs, interrupted service occurrence logs) going back as far as 2001. Data will be supplied on a DVD.

Timeline Schedule for Data Collection

Travel Time Runs (Arterial and Freeway Locations)

Following the boundaries of the study area as shown in Figure B-1, Table B-7 lists the locations of the travel time runs that have been requested from the subcontracted data collection firm, *National Data & Surveying Services (NDS)*. Travel time runs are being conducted along the freeway and arterials during the a.m. peak period between the hours of 5:00 and 9:00 a.m. beginning the week of January 5, 2009. Two runs are being conducted for each segment during a period of two typical weekdays (Tuesday, Wednesday, or Thursday), for a total of four runs per location.

Arterial Data Collection

There are 106 arterial intersections listed in Table B-4 for which turning movement counts are being collected by NDS between the hours of 5:00 and 10:00 a.m., beginning the week of January 5, 2009. Of the 106 arterial intersections, 91 require one person, while the remaining 15 intersections require two persons to collect the data.

Table B-7. Travel Time Runs Locations

Location	From	To
Pomerado Road	I-15	Highland Valley Road
Centre City Parkway	I-15	I-15
Rancho Bernardo Road	Pomerado Road	Camino Del Norte
Camino Del Norte	Pomerado Road	Rancho Bernardo Road
Ted Williams Parkway (SR 56)	Pomerado Road	Black Mountain Road
Black Mountain Road	Pomerado Rd/Miramar Road	SR 56
Scripps Parkway/Mercy Road	Pomerado Road	Black Mountain Road
I-15 Southbound and Northbound	SR 52	SR 78

Freeway Data Collection

Tables B-6 and B-7 depict the I-15 on- and off-ramp locations of available PeMS data and data gaps. This data is not, however, being collected because the physical configuration has changed from that which existed in 2003. Moreover, time and resource constraints also have contributed to this data not being collected.

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