Integrated Corridor Management I-15 San Diego, California

Analysis Plan

www.its.dot.gov/index.htm

Final Report – February 2010
FHWA-JPO-10-039
EDL Number 14946

U.S. Department of Transportation
Research and Innovative Technology Administration

Produced by FHWA Office of Operations Support Contract DTFH61-06-D-00004
U.S. Department of Transportation
Federal Highway Administration

Notice

Technical Report Documentation Page

1. Report No. **FHWA-JPO-10-039**	**2. Government Accession No.** **EDL No. 14946**	**3. Recipient's Catalog No.**
4. Title and Subtitle Integrated Corridor Management I-15 San Diego, California – Analysis Plan		**5. Report Date** February 2010 **6. Performing Organization Code**
7. Author(s) Albinder Dhindsa, Vassili Alexiadis, Alex Estrella, Mike Miller, Meenakshy Vasudevan, Mike Calandra, Ellison Allegre, and Saurabh Kumar		**8. Performing Organization Report No.**
9. Performing Organization Name And Address Cambridge Systematics, Inc. 555 12th Street, Suite 1600 Oakland, California 94607		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-06-D-00004
12. Sponsoring Agency Name and Address U.S. Department of Transportation Research and Innovative Technology Administration (RITA) 1200 New Jersey Avenue, SE Washington, DC 20590		**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code** HOP
15. Supplementary Notes The COTM for FHWA is Dale Thompson.		

16. Abstract

This AMS Analysis Plan for the I-15 Corridor outlines the various tasks associated with the application of the ICM AMS tools and strategies to this corridor in order to support benefit-cost assessment for the successful implementation of ICM. The report provides a brief description of the I-15 Corridor in San Diego, California, and the methodology used for the AMS. It lays out ICM strategies that will be tested and provides a list of the AMS scenarios. This report then defines performance measures that will be utilized in the analysis of the ICM strategies on the Pioneer Corridor and sets out the simulation model calibration requirements and the data needs for this calibration. Finally, the last two sections present an overview of the Pioneer Corridor AMS document that will be developed to summarize the results of the AMS effort and provides a schedule and a resource guide for the AMS tasks. Appendixes are included that provide detailed lists of prioritized ICM strategies and scenarios for San Diego, provide the Data Collection Plan for the AMS effort, provide the draft methodology memorandum for calculating travel time reliability for the AMS effort, and describe the method employed to estimate transit mode shift.

17. Key Words Integrated Corridor Management, ICM, mesoscopic models, cluster analysis, incident, strategies, traveler information, pioneer corridor, analysis plan, Analysis Modeling Simulation (AMS), performance measures, San Diego, California, CA, I-15	**18. Distribution Statement** No Restrictions.		
19. Security Classif. (of this report) unclassified	**20. Security Classif. (of this page)** unclassified	**21. No. of Pages** 92	**22. Price** NA

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

Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction and Background

The objective of the ***Integrated Corridor Management (ICM)*** initiative is to demonstrate how intelligent transportation systems (ITS) technologies can efficiently and proactively manage the movement of people and goods in major transportation corridors. The ICM initiative aims to pioneer innovative multimodal and multi-jurisdictional 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, bus rapid transit (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 multi-agency 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.

The objectives of the ***"ICM – Tools, Strategies and Deployment Support"*** project are to refine Analysis Modeling and Simulation (AMS) tools and strategies, assess Pioneer Site data capabilities, conduct AMS for three Stage 2 ICM Pioneer Sites, and conduct AMS tools post-demonstration evaluations. Current efforts under this project focus on analyzing the ICM systems proposed by the Stage 2 Pioneer AMS Sites and evaluating the expected benefits to be derived from implementing those ICM systems.

The overall benefits of this effort include:

- Help decision-makers identify technical and implementation gaps, evaluate ICM strategies, and invest in the best combination of strategies that would minimize congestion and improve safety; comprehensive modeling increases the likelihood of ICM success and help minimize unintended consequences of applying ICM strategies to a corridor.
- Help estimate the benefit resulting from ICM across different transportation modes and traffic control systems; 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.

- Transfer knowledge about analysis methodologies, tools, and possible benefits of ICM strategies to the Pioneer Sites and to the entire transportation community.

This ***AMS Analysis Plan for the I-15 Corridor*** outlines the various tasks associated with the application of the ICM AMS tools and strategies to this corridor in order to support benefit-cost assessment for the successful implementation of ICM. The organization of this analysis plan is as follows:

- Chapter 2 provides a brief description of the I-15 Corridor in San Diego, California, and the methodology used for the AMS;
- Chapter 3 lays out ICM strategies that will be tested and provides a list of the AMS scenarios;
- Chapter 4 defines performance measures that will be utilized in the analysis of the ICM strategies on the Pioneer Corridor;
- Chapter 5 sets out the simulation model calibration requirements and the data needs for this calibration;
- Chapter 6 presents an overview of the Pioneer Corridor AMS document that will be developed to summarize the results of the AMS effort;
- Chapter 7 provides a schedule and a resource guide for the AMS tasks;
- Appendix A provides the detailed list of prioritized ICM strategies and scenarios for San Diego;
- Appendix B provides the Data Collection Plan for the AMS effort;
- Appendix C provides the draft methodology memorandum for calculating travel time reliability for the AMS effort; and
- Appendix D describes the method employed to estimate transit mode shift.

1.1 Principles in Developing and Applying the Analysis Plan

A number of principles apply in developing and applying the Analysis Plan. These are summarized as follows:

- **Resource and schedule constraint –** The overall ICM AMS effort must take place within the budget and schedule specified in the Analysis Plan. Data, models, and tools available at the Pioneer Site will be leveraged in the AMS effort.
- **Focus on integration of existing tools –** The ICM AMS effort does not focus on developing new analytical tools; instead, it focuses on a relevant, meaningful application of **existing** modeling and simulation tools.
- **Recognize current limitations in available tools and data –** There are known gaps in existing analysis tools that the AMS methodology must bridge. Examples of these gaps include the dynamic analysis of transit and mode shift, and the dynamic analysis of ICM strategies such as traveler information or congestion pricing. Bridging these gaps requires the interface of existing analysis tools with different capabilities.

- **Consistency of analytical approaches and performance measures –** ICM Pioneer Sites have different analysis tools at their disposal. The application of the AMS methodology to the various Pioneer Sites must be consistent in terms of analysis approach and performance measures. Consistency is important when trying to synthesize lessons learned in each site into national-level guidance.
- **Benefit-cost analysis –** Expected benefits resulting from the implementation of ICM strategies will be compared to expected costs to produce estimates of benefit-cost ratios and net benefits associated with the deployment of ICM strategies. This analysis will be conducted per performance measure benefit to help identify cost-effective ICM strategies, help differentiate between low-payoff and high-payoff ICM strategies, and help prioritize ICM investments based on expected performance.

Chapter 2 I-15 Corridor Site and AMS Methodology

The Pioneer Site identified for this analysis is the Interstate 15 corridor in San Diego, California. The corridor extends from the interchange with State Road (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 following roadways:

- Centre City Parkway;
- Pomerado Road;
- Rancho Bernardo Road;
- Camino Del Norte Road;
- Ted Williams Parkway;
- Black Mountain Road; and
- Scripps Parkway.

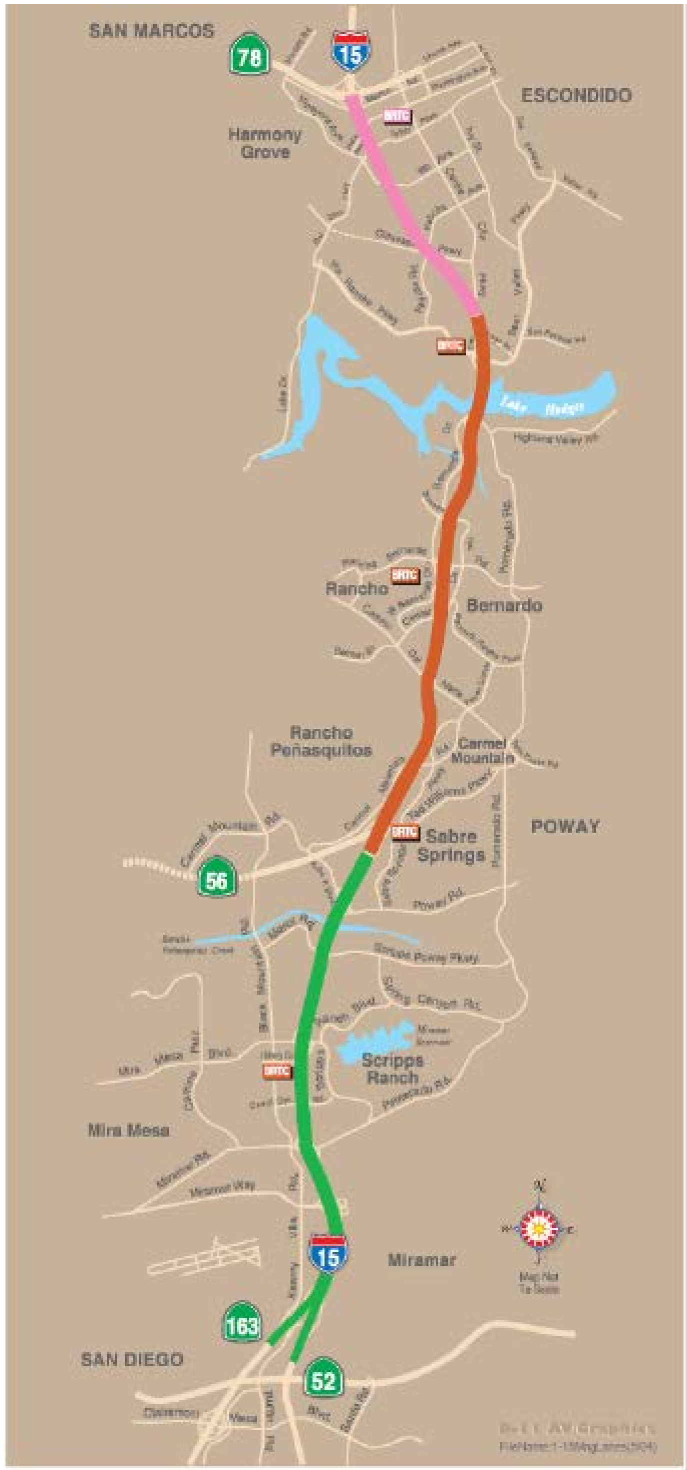
Figure 2-1 illustrates the study area routes that will be utilized for analysis at this Pioneer Site. The I-15 corridor in San Diego will be utilized as a test bed for various ITS strategies identified in consultation with the San Diego Association of Governments (SANDAG) and other local stakeholders. These strategies are identified and explained in Chapter 3 of this document. The following sections provide a detailed overview of the study corridor and describe the process for the ICM analysis.

2.1 I-15 Corridor Description

Figure 2-1 illustrates the Pioneer Corridor and the roadways included in the study area. I-15 is an eight- to 10-lane freeway section in San Diego providing an important connection between San Diego and cities like Poway, Mira Mesa, and Escondido, and destinations to the northeast. Figure 2-2 indicates the geographic location of the corridor along with the extents of the mainline study area.

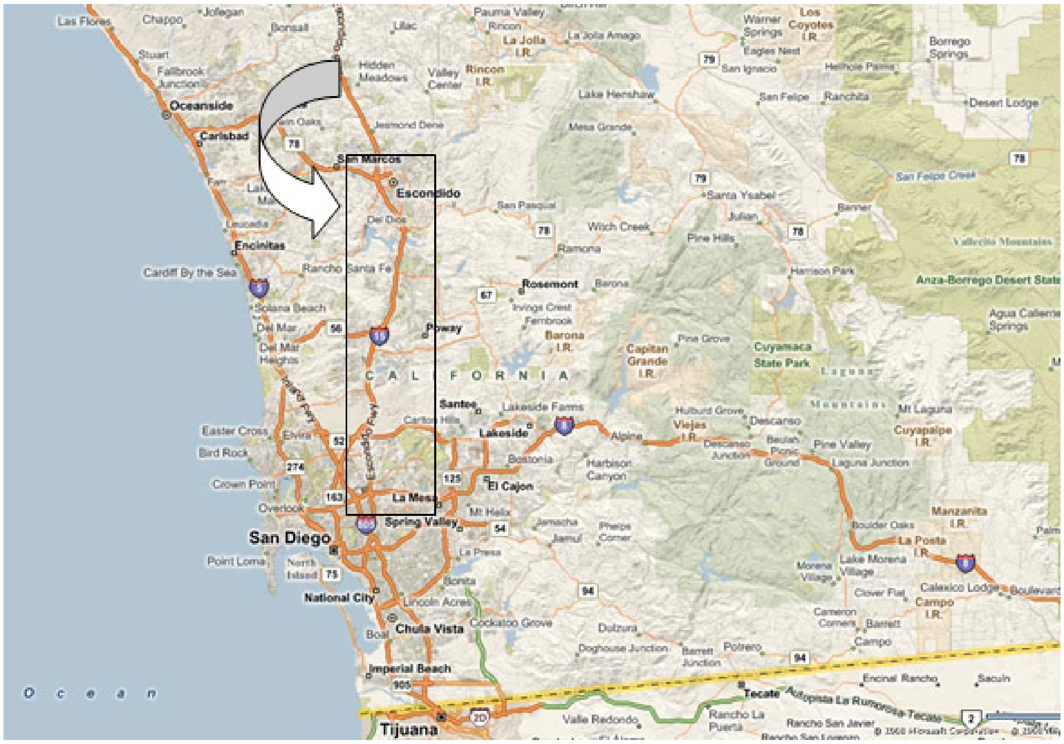
The current operations on I-15 include two center-median lanes that run along eight miles of I-15 between SR 163 in south and Ted William Pkwy (SR 56) in the north. These center-median lanes are reversible high-occupancy vehicle (HOV) lanes that operate in the southbound direction in the A.M. peak period and in the northbound direction during the P.M. peak period. The current operations also allow single occupancy vehicles (SOV) to utilize the roadway for a price, thereby operating as high-occupancy toll (HOT) lanes.

Figure 2-1. Study Area – I-15 Corridor in San Diego, California



[Source: SANDAG: AV Graphics.]

Figure 2-2. Location and Geographic Boundaries of Corridor



[Source: ©Microsoft Corporation ©NAVTEC ©AND.]

The section between SR 78 and SR 163 (study area) will eventually include four center median lanes, which will have two lanes in each direction operating as HOT lanes in the peak direction. According to the Concept of Operations 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.

2.2 Modeling Approach

The modeling approach that emerged from the analysis of capabilities found in existing AMS tools as well as from the ICM Test Corridor project is an ***integrated platform that can support corridor management planning, design, and operations by combining the capabilities of existing tools.*** The overall integrated approach is based on ***interfacing travel demand models, mesoscopic simulation models, and microscopic simulation models***. The Pioneer Corridor AMS approach encompasses tools with different traffic analysis resolutions. All three classes of simulation modeling approaches – macroscopic, mesoscopic, and microscopic – may be applied for evaluating ICM strategies.

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

In this AMS framework, macroscopic, mesoscopic, and microscopic traffic analysis tools can interface with each other, passing trip tables and travel times back and forth looking for natural stability within the system. Absolute convergence may not be achieved because of inherent differences at the various modeling levels. This methodology will seek a natural state for practical convergence between different models, and the iterative process will be terminated or truncated at a point where reasonable convergence is achieved. This iterative process will include the use of mode shift, time-of-day shift, and dynamic assignment during the calibration process.

The paragraphs below provide an overview of the various modeling components that are anticipated to be utilized in the AMS modeling framework.

Travel Demand Forecasting Model

Predicting travel demand requires specific analytical capabilities, such as the consideration of destination choice, mode choice, time-of-day travel choice, and route choice, as well as the representation of traffic flow in the highway network. These attributes are found in the structure and orientation of travel demand models, which serve as mathematical models that forecast future travel demand from current conditions and future projections of household and employment characteristics.

SANDAG's Travel Demand Model (TDM) for the region will be used to develop the trip tables and networks for the I-15 Corridor. Sub-area trip tables and networks will be developed from the TDM – for use in the simulation models. Parameters from the TDM also will be used to analyze mode shifts in response to congestion and to ICM strategies.

Mesoscopic Simulation Model

Mesoscopic models combine properties of both microscopic and macroscopic simulation models. The mesoscopic models' unit of traffic flow is the individual vehicle, and the model assigns vehicle types and driver behavior, and also takes into account their relationships with the roadway characteristics. The movements in a mesoscopic model, however, follow the approach of macroscopic models and are governed by the average speed on the travel link. Mesoscopic models provide less fidelity than microsimulation tools, but are superior to travel demand models in that, mesoscopic models can evaluate dynamic traveler diversions in large-scale networks.

As part of the AMS effort for I-15, the mesoscopic tools have not been used, and most of the functions have been incorporated through the microscopic tools.

Microscopic Simulation Model

Microscopic simulation models simulate the movement of individual vehicles, based on theories of car-following and lane-changing. Typically, vehicles enter a transportation network using a statistical distribution of arrivals (a stochastic process) and are tracked through the network over small time intervals (e.g., one second or fraction of a second.) Typically, upon entry, each vehicle is assigned a destination, a vehicle type, and a driver type. In many microscopic simulation models, the traffic operational characteristics of each vehicle are influenced by vertical grade, horizontal curvature, and superelevation, based on relationships developed in prior research. The primary means of calibrating and validating microscopic simulation models is through the adjustment of driver sensitivity factors.

For the analysis of this corridor the microscopic component of TransModeler will be utilized. The microsimulation model will support the evaluation of traffic control aspects of ICM strategies, such as freeway ramp metering and arterial traffic signal coordination, as well as managed-use lane operations. At any time the route choice model can be reevaluated in order to update the path choices of drivers en route to their destinations. This model will be used to evaluate the response of drivers in incident situations when they are faced with high levels of congestion. When a driver's path choice is reevaluated, the path costs (e.g., segment travel times) are reconsidered. For driver groups defined in the model parameters as having access to real-time travel information (i.e., informed drivers), an updated travel time table can be used to evaluate path costs. Drivers belonging to a driver group that does not have access to real-time information will reconsider their paths using the same (i.e., historical) travel time information used to evaluate their pre-trip paths.

In addition, the microsimulation model will be used to evaluate the nature of temporal mitigation decisions that need to be taken in response to congestion. The microsimulation model operates by simulating all the key system components such as signals, meters, speed limits, and transit vehicles, so it can be utilized to identify and test different congestion hotspots.

The traffic assignment models within TransModeler allow the use of static and dynamic assignment procedures based on requirements of different study types. Traffic assignment models are used to estimate the flow of traffic on a network. These models take as input a matrix of flows that indicate the volume of traffic between origin and destination (O-D) pairs. The flows for each O-D pair are loaded onto the network based on the travel time or impedance of the alternative paths that could carry this traffic. For traffic simulation models, the flow on a network is modeled by representing individual vehicle movements, and subsequently the link-based performance measures are evaluated based on movements of these individual vehicles as they rest in queues, travel in free flow, or maneuver through congestion. Whether all vehicles traveling a given path reach all links on the path within a given analysis period is dependent on time-variant travel conditions in the network. [1]

The key behavioral assumptions underlying the User Equilibrium assignment model are that every traveler has perfect information concerning the attributes of network alternatives, all travelers choose a route that minimizes their travel time or travel costs, and all travelers have the same valuations of network attributes. At user equilibrium (UE), no individual travelers can unilaterally reduce their travel time by changing paths (Sheffi, 1985). A consequence of the UE principle is that all used paths for an O-D pair have the same minimum cost. An alternative and more realistic equilibrium model was proposed by Daganzo and Sheffi (1977) known as Stochastic User Equilibrium or SUE. This model is premised on the assumption that travelers have imperfect information about network paths and/or vary in their perceptions of network attributes. At stochastic user equilibrium, no travelers believe that they can increase their expected utility by choosing a different path. Because of variations in traveler perceptions and also in the level of service experienced, utilized paths do not necessarily have iden-

[1] Transmodeler User Manual.

tical generalized costs. The SUE model is consistent with the concept of applying discrete choice models for the choice of route, but with the necessary aggregation and equilibrium solution.

For the current analysis, SUE is utilized for calibration and validation of the base year model. The use of SUE also is consistent with the utilization of managed use lane scripts which utilize the cost of different paths with a logit based route choice model, to assign en-route mode and route choice. Details on the use of the logit model are provided in Appendix D.

Time-of-Departure Choice

The methodology used in the I-15 AMS assumes that the level of congestion along the shortest path between any O-D pair will affect the degree of peak spreading that is likely to occur for that O-D pair. This methodology is based on a set of temporal distributions that vary by the ratio of the Average Daily Traffic to hourly Capacity (ADT/C). It has the effect of moving demand from peak hours to off-peak hours as congestion increases, which becomes especially important as future year traffic volumes grow. The shift in demand from peak hours to off-peak hours is directly proportional to the level of congestion on the route thereby simulating an effective change in the departure choice of the drivers. The time-of-departure (TOD) choice will be implemented for the base year model and calibrated based on the 24-hour trip tables from the regional travel demand model. The future year will utilize 2012 future volumes and a TOD adjustment based on the ADT/C ratios in the future networks. However, the future number of trips in the O-D shall be the same for all the alternatives analyses.

The main input to simulation models in travel demand is in the form of O-D tables. Ideally, these O-D tables come from regional travel demand models and represent travel demand in small time increments, usually 15-minute slices, to support the dynamic traffic assignment process. Unfortunately, most regional travel demand models, including SANDAG's, are calibrated and validated to much longer time periods and are estimated by applying regional factors to every O-D pair based on observations from a travel survey. These same factors are usually applied to future year forecasts as well. This approach therefore assumes that the temporal distribution of trips is constant by geography, regardless of the location and longevity of congestion.

The employed methodology for the I-15 AMS assumes a different temporal distribution for every O-D pair and is related to the level of congestion between each O-D pair. For O-D pairs that experience little or no congestion, no peak spreading will occur. For O-D pairs that experience high congestion levels, significant peak spreading will occur and will continue to spread as congestion increases over time. In other words, the level of temporal redistribution is sensitive to changes in demand over time or in response to changes in supply.

The estimation of hourly demand is sensitive to changes in supply and/or demand assuming that the amount of temporal spreading that is likely to occur between any O-D pair is based on the level of congestion that is present along the shortest path between that particular O-D pair. A set of temporal distributions were developed by Margiotta[2] et al. that vary based on the level of congestion as measured by the daily volume to hourly capacity ratio (ADT/C). These distributions were developed as a mechanistic way of moving demand from one time period to another as the level of congestion

---

[2] Margiotta, R., H. Cohen, and P. DeCorla-Souza, *Speed and Delay Prediction Models for Planning Applications*, Sixth National Conference on Transportation Planning for Small and Medium-Sized Communities, Spokane, Washington, 1999.

changes. Table 2-1 shows the initial average weekday temporal distributions by two-way ADT/C. It was determined that direct application of these distributions could lead to illogical results if ADT/C values are at the boundary (e.g., ADT/C = 11). Therefore, a smoothing procedure was developed to account for these boundary problems and provide distributions for ADT/C ratios above 13. Finally, different sets of curves were developed[3] *for each trip purpose as the temporal distribution varies by trip type. For example, home-based work trips have a temporal distribution that is quite different than a home-based shopping trip.*

Table 2-1. Initial Weekday Temporal Distribution by Two-Way ADT/C

Hour	< = 7	7 – 11	> 11	Hour	< = 7	7 – 11	> 11
1	1.00	1.01	1.01	**13**	5.36	5.43	5.53
2	0.60	0.61	0.59	**14**	5.47	5.56	5.68
3	0.48	0.48	0.44	**15**	6.05	6.08	6.12
4	0.45	0.42	0.36	**16**	7.27	7.08	6.81
5	0.67	0.63	0.56	**17**	8.28	7.81	7.10
6	1.85	1.81	1.78	**18**	8.27	7.71	7.06
7	5.01	5.06	5.04	**19**	5.89	5.86	6.04
8	7.73	7.64	7.17	**20**	4.18	4.22	4.48
9	6.13	6.56	6.70	**21**	3.32	3.33	3.48
10	4.82	5.05	5.47	**22**	3.03	3.13	3.28
11	4.79	4.84	5.17	**23**	2.44	2.58	2.73
12	5.12	5.22	5.42	**24**	1.77	1.88	1.96

For the I-15 AMS, these temporal distributions will be refined to represent local conditions in the San Diego region by applying the models for the base year, summing the hourly trips to the peak period, and comparing to the SANDAG travel model's peak-period trip totals for each trip purpose. Additionally, the process being utilized to calibrate the base year travel demand, Origin Destination Matrix Estimation (ODME), further refines the O-D tables to local conditions.

Analysis of Mode Shift and Transit

A known gap in the analysis of ICM relates to the performance and impacts of transit services. Mode shift in the Pioneer Corridor can be influenced by adverse traffic conditions (incidents, heavy demand, and inclement weather) and by ICM strategies (such as traveler information systems.) Modeling of mode shift requires input of transit travel times, which are calculated by network segment and at key decision points in the corridor. This can support comparison of network and modal alternatives, and

[3] Simons, C., I-285 *Matrix Variegator: Practical Method for Developing Trip Tables for Simulation Modeling from Travel Demand Modeling Inputs*, Transportation Research Board, Journal Article, Volume 1961, Washington, D.C., 2006.

facilitate the analysis of traveler shifts among different transportation modes. For the San Diego I-15 Corridor, the available mode choice models were identified and their applicability was explored.

In order to identify the base mode shift, the mode-choice component of the SANDAG travel demand model was utilized. This component calculates the number of vehicles at the beginning of simulation that decide to drive as opposed to take transit. After this mode split is set, there also is the need to model users' choice of mode as en-route information becomes available to them. This is applicable to the I-15 corridor for two reasons: First, the corridor currently is being equipped with reversible HOT lanes that also will serve a corridor-wide BRT service. The BRT service is proposed to have five stations within the study corridor, each having direct connections to the HOT lane and also access to the General Purpose Lanes. This combination allows for significant mode shift opportunities especially in occurrence of an event such as a major incident. Secondly, the analysis is being conducted at a microsimulation level, where the behavior of every driver in the simulation can be monitored and modified, if necessary, and this behavior does impact the operation of the model.

Once the initial mode-share is available at start-up, the availability of en-route information would cause drivers to modify their route choices as well as mode choices. Driver groups will be provided with different levels of quality of information. Drivers equipped with Global Positioning System (GPS) devices and those that are 511 users will be assumed to make their decision based on real-time information on managed lane and general purpose lane travel times, as well as transit travel time information. Drivers without in-vehicle GPS or 511-based information will be assumed to consider route- or mode-shift based on VMS-posted information only. The perception of travel times for the two categories of drivers will be different: more GPS or 511 users will consider mode- or route-shift than drivers who get their traveler information from VMS.

The detailed methodology for modeling this en-route mode shift is presented in Appendix D, which details the key variables and assumptions utilized in modeling mode shift to BRT as well as HOT lanes.

Chapter 3 Analysis Scenarios and ICM Strategy

This section provides an overview of priority ICM strategies for this Pioneer Corridor and the scenarios that will be studied to analyze the impacts of these strategies. The analysis will assist local agencies to:

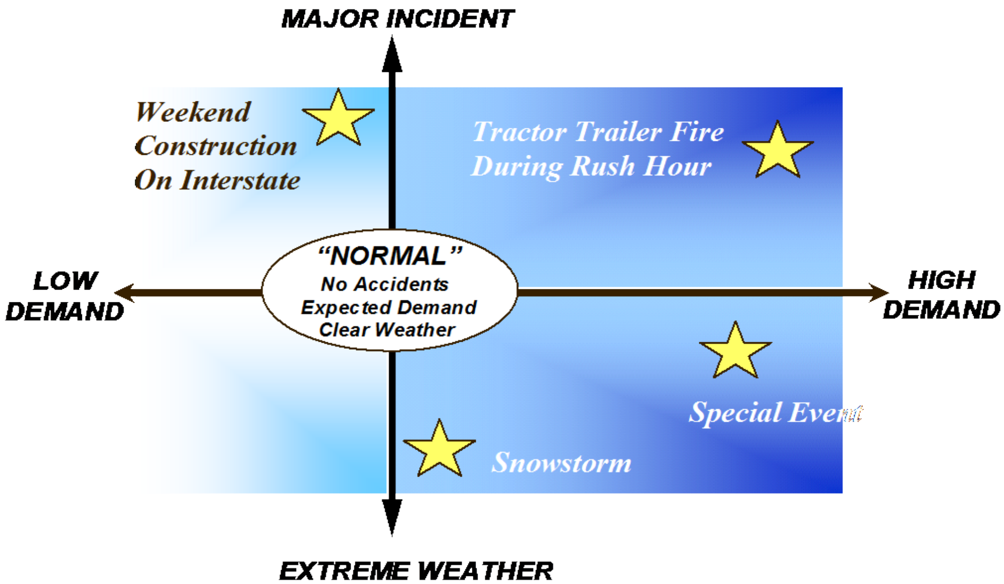
- **Invest in the right strategies –** The analysis offers corridor managers a predictive forecasting capability that they lack today to help them determine which combinations of ICM strategies are likely to be most effective under which conditions;
- **Invest with confidence –** AMS will allow corridor managers to “see around the corner” and discover optimum combinations of strategies, as well as conflicts or unintended consequences inherent in certain combinations of strategies that would otherwise be unknowable before implementation;
- **Improve the effectiveness/success of implementation –** With AMS, corridor managers can understand in advance what questions to ask about their system and potential combinations of strategies to make any implementation more successful; and
- AMS provides a long-term capability to corridor managers to **continually improve implementation** of ICM strategies based on experience.

3.1 Analysis Scenarios

The I-15 AMS Analysis Plan provides tools and procedures capable of supporting the analysis of both recurrent and nonrecurrent congestion scenarios. The Pioneer Corridor nonrecurrent congestion scenarios entail combinations of increases of demand and decreases of capacity. Figure 3-1 depicts how key ICM impacts may be lost if only “normal” travel conditions are considered. The relative frequency of nonrecurrent conditions also is important to estimate in this process – based on archived traffic conditions, as shown in Figure 3-2.

The proposed analysis scenarios for the I-15 AMS focus on the high-demand periods during a typical day, with and without incidents. The nonrecurrent congestion scenarios modeled for this corridor include some incident scenarios that were identified in the Concept of Operations document. The typical day is identified based on PeMS data for I-15 from April to May and September to November of the base year, and choosing the weekday closest to the average volume for the entire peak season. The determination of the closeness is based on a calculation of the deviation for the entire time series. The volumes from this day will be balanced to reflect the conservation of flow on the corridor.

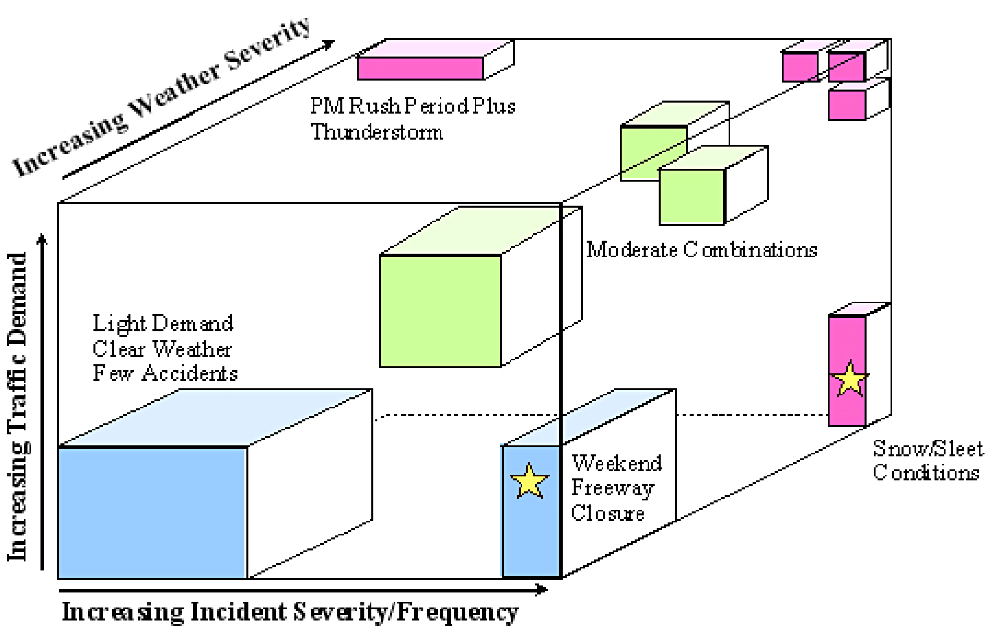
Figure 3-1. Key ICM Impacts May Be Lost If Only "Normal" Conditions Are Considered



[Source: Wunderlich, K., et al., Seattle 2020 Case Study, PRUEVIIN Methodology, Mitretek Systems. This document is available at the Federal Highway Administration (FHWA) Electronic Data Library (http://www.itsdocs.fhwa.dot.gov/).]

Figure 3-2. Sources of System Variation

Classifying Frequency and Intensity



[Source: Wunderlich, K., et al., Seattle 2020 Case Study, PRUEVIIN Methodology, Mitretek Systems. This document is available at the FHWA Electronic Data Library (http://www.itsdocs.fhwa.dot.gov/).]

For the purposes of this study, an analysis of incident and demand data was undertaken by the project team. The primary source of incident data was the CHP and TASAS database within PeMS and the focus of the examination was on incidents that occurred on the southbound general purpose lanes of I-15 between Post Miles 15 and 35 during the Baseline year of 2003.

The analysis focused on the distribution of the number of days in 2003 by incident type and by travel demand level during the A.M. peak period over the course of the baseline year as shown in Tables 3-1 and 3-2. Demand is measured in terms of vehicle miles traveled (VMT) and demand levels are divided into three categories – low, medium, and high – based on their percentage of median VMT as follows:

- Low, if VMT is less than 75 percent of the median VMT value;
- Medium, if VMT is greater than 75 percent of and less than 102 percent of the median VMT value; and
- High, if VMT is greater than 102 percent of the median VMT value.

This classification was based on an analysis of demand bins of all the days in 2003, for the A.M. peak period. The nature of the I-15 corridor, being a linear access facility with limited alternative freeway options, makes the typical weekday demand fall in the high demand classification.

As shown in Table 3-1, a total of 171 days (i.e., close to 47 percent of the days operate in the same demand bin) have demands that fall within the high demand class. The significance of this for analysis is the potential share of performance measures derived for the high demand cases.

Table 3-1. Distribution of Number of Days in 2003 by Incident Type and by Demand Level

		Incident			
Number of Days in a Year		**Major**	**Minor**	**No Incident**	**Total**
Demand	High	38	5	128	171
	Medium	17	4	60	81
	Low	31	1	81	113
Total		**86**	**10**	**269**	**365**

Table 3-2 also shows that there is strong correlation between the number of days with incidents and number of days with high demand, with close to 45 percent of the incidents taking place within the same demand class. The table also provides the absolute distribution of different demand-incident scenarios, and counts any day with one or more incidents. While close to 74 percent of the days are showing normal operations during the peak period, around 10 percent of the days in the year have major incidents occur during high demand regime.

Table 3-2. Percentage Distribution of Number of Days in 2003 by Incident Type and by Demand Level

Number of Days in a Year		Incident			
		Major	**Minor**	**No Incident**	**Total**
Demand	High	10.4%	1.4%	35.1%	46.8%
	Medium	4.7%	1.1%	16.4%	22.2%
	Low	8.5%	0.3%	22.2%	31.0%
Total		**23.6%**	**2.7%**	**73.7%**	**100.0%**

Tables 3-3 and 3-4 also show the distribution of vehicle hours of delay in 2003 by incident type and by travel demand level during the A.M. peak period over the course of the baseline year. The most striking, yet not surprising, element of the data from these tables is the observation that total delay associated with low level of demand contributes only negligible amounts to total delay.

Table 3-3. Distribution of Vehicle Hours of Delay in 2003 by Incident Type and by Demand Level

Delay		Incident			
		Major	**Minor**	**No Incident**	**Total**
Demand	High	109,304	18,276	381,466	509,046
	Medium	70,040	23,724	265,704	359,468
	Low	123	0	295	418
Total		**179,467**	**42,000**	**647,465**	**868,932**

Table 3-4. Distribution of Percentage of Delay in 2003 by Incident Type and by Demand Level

Percentage of Delay		Incident			
		Major	Minor	No Incident	Total
Demand	High	12.6%	2.1%	43.9%	58.6%
	Medium	8.1%	2.7%	30.6%	41.5%
	Low	0.0%	0.0%	0.0%	0.0%
Total		20.7%	4.8%	74.5%	100.0%

Table 3-2 shows that low demand conditions with minor incidents occurred only one day in the year, leading to negligible amounts of delay as compared to the other conditions (viz. high demand and major incident), as shown in Table 3-3.

In addition to the above analysis that determines the percentages (probabilities) of occurrence of different demand and incident combinations, additional analysis looked at incident and incident frequency versus volume-to-capacity ratio (V/C) during average weekdays; that is, Tuesdays, Wednesdays, and Thursdays, to better understand nonrecurring congestion during various times of such days.

There were a total of 432 incidents for this study road section that occurred not just during the A.M. peak period, but also the P.M. and off-peak periods. During the off-peak, A.M. peak, and P.M. peak periods there were 268, 100, and 64 incidents, respectively, in the southbound I-15 direction. Figures 3-3 and 3-4 show the relationships between the number of incidents and their frequency to V/C ratios for both off-peak and peak-hour incidents, respectively. When the V/C ratio is relatively low (<0.65), the incident frequency in the off-peak period is always higher than that of the peak period. When the V/C ratio is relatively high (>=0.65), the incident frequency for the off-peak period is always lower than that for the peak hour. The maximum incident frequency for the off-peak period (approximately 1.8 incidents per mile for V/C ratio 0.5 to 0.55) is higher than for the peak period (1.2 incidents per mile for V/C ratio 0.7 to 0.75).

Figure 3-3. Distribution of the Number of the Incidents by V/C Ratio

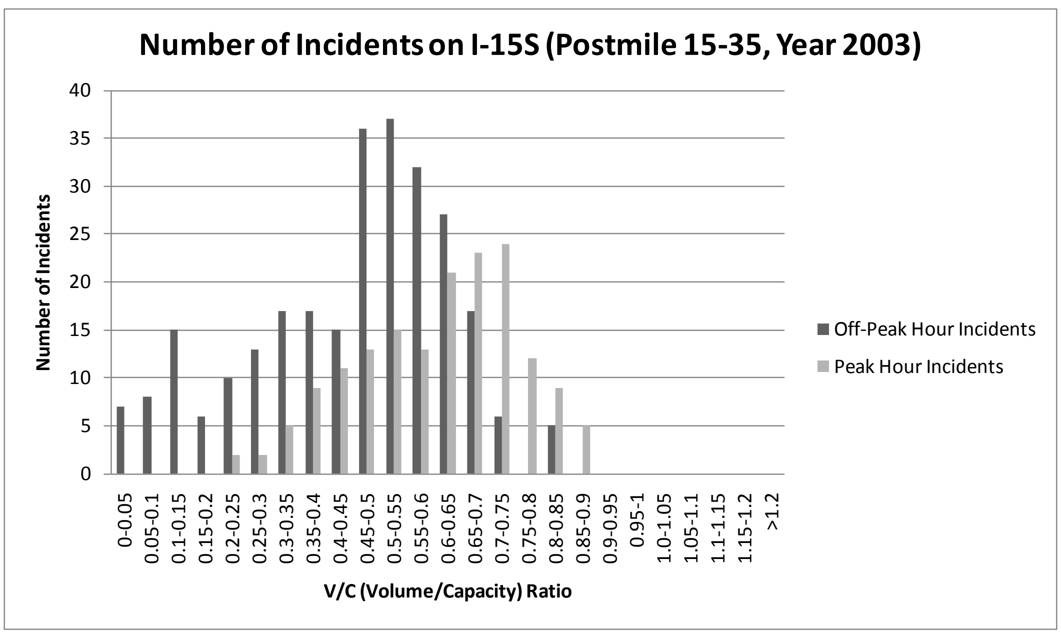
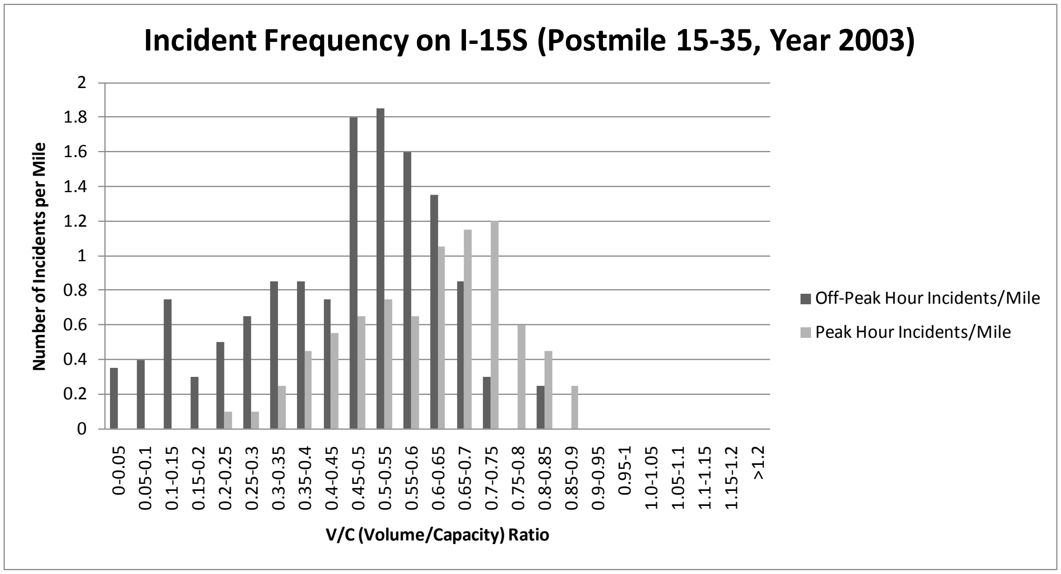


Figure 3-4. Distribution of Incident Frequency by V/C Ratio



Figures 3-5 and 3-6 show similar trends for the A.M. peak period. The maximum incident frequency for the A.M. peak period is 0.85 incident/mile for a V/C ratio range 0.65 to 0.75.

Figure 3-5. Distribution of the Number of the Incidents by V/C Ratio for the A.M. Peak

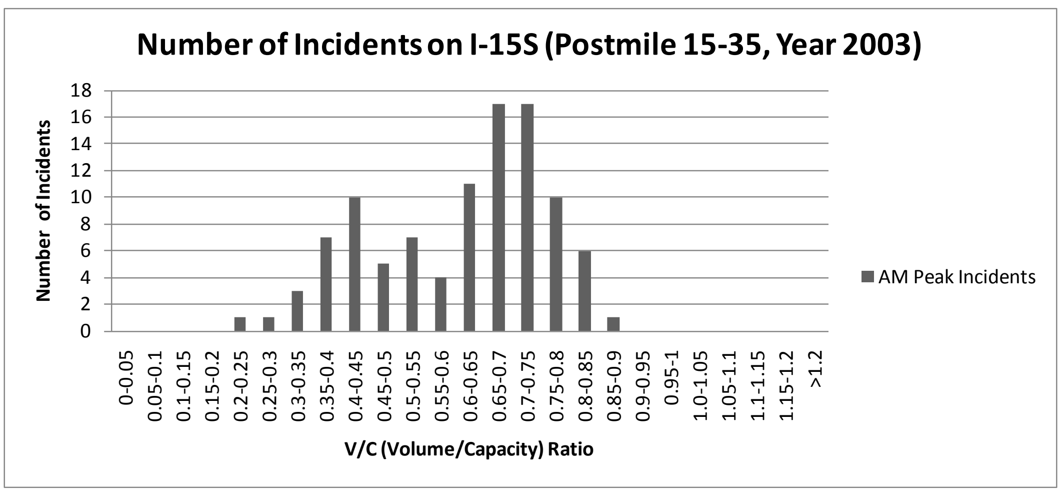
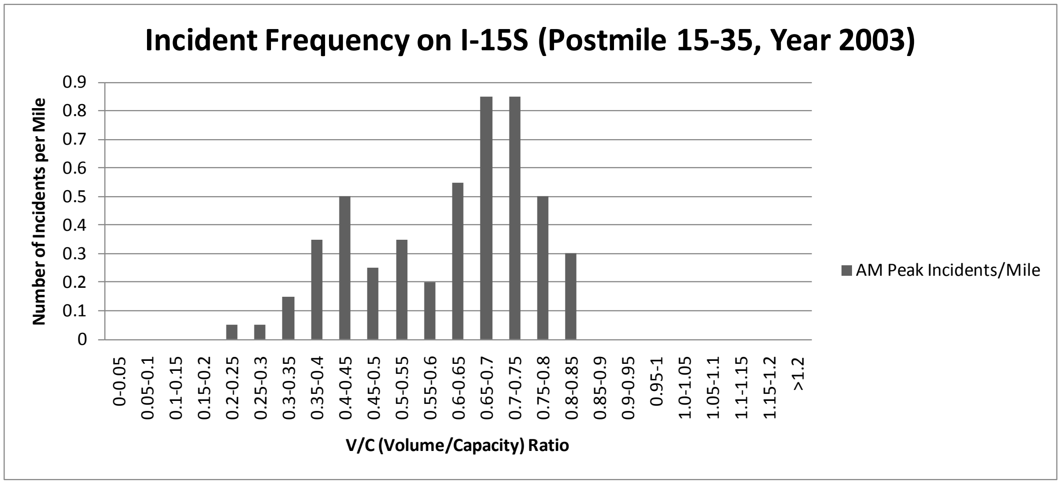


Figure 3-6. Distribution of Incident Frequency by V/C Ratio for the A.M. Peak



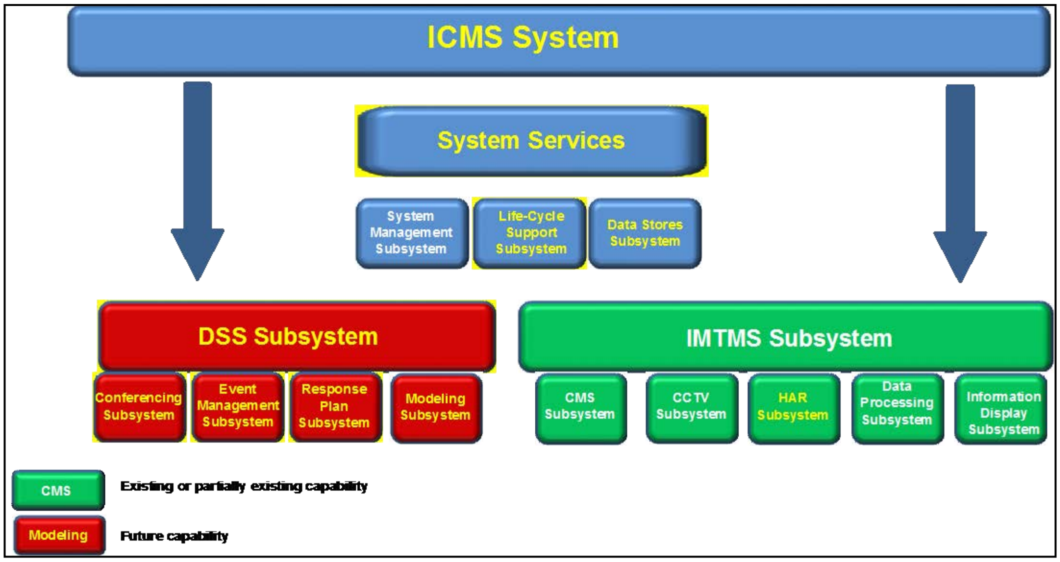
This analysis will be used to identify locations in the corridor, where V/C ratios determine safety impacts of different ICM strategies.

The San Diego region has made significant capital investments in transit, highway, and arterial systems to derive maximum ITS benefits, while focusing on data sharing. SANDAG, its member agencies, and diverse stakeholders are attempting to optimize operational coordination of multiple transportation networks and cross-network connections to improve corridor mobility within the region. The I-15 corridor represents one of the efforts furthest along in developing such a framework that integrates a monitoring and management system providing information to a Decision Support System (DSS) for incident response.

Figure 3-7 shows the I-15 Operational Concept, and depicts the components of this concept that already have been implemented and those that need to be implemented. The ones that need to be implemented represent the area of maximum benefit for a modeling analysis to help build a DSS by using the AMS to identify necessary components of the decision-making. Among the components that are being implemented is the Intermodal Transportation Management System (IMTMS).

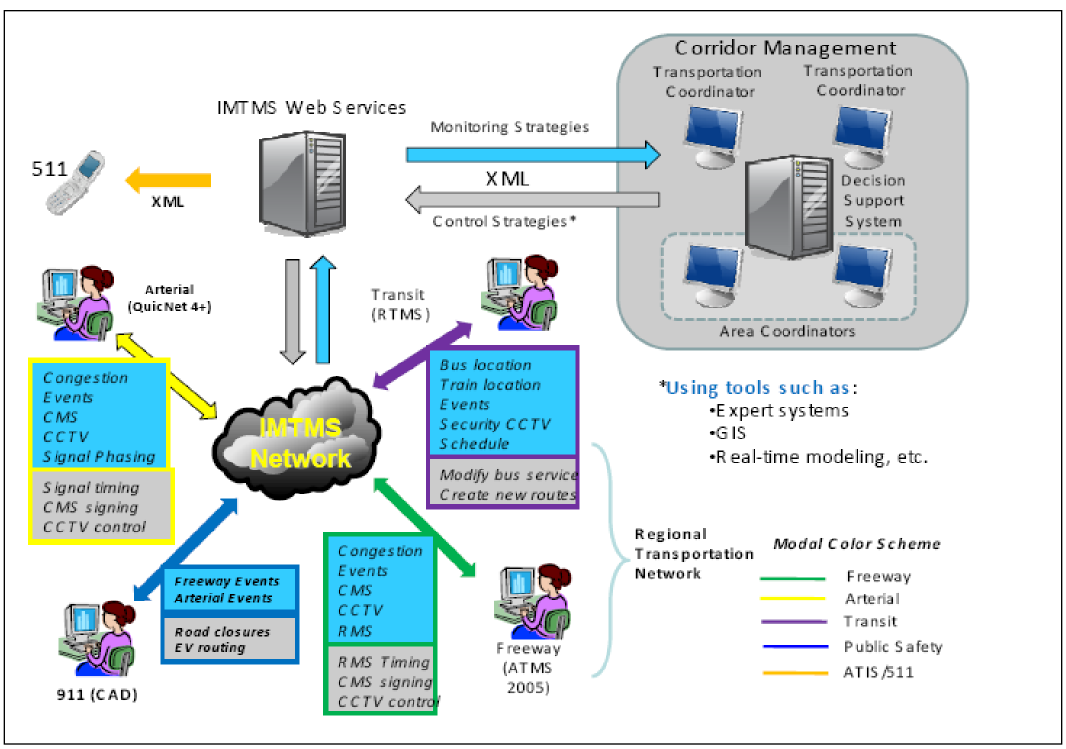
IMTMS became operational in May 2007, and has a modular, standards-based web service architecture that helps collect information from a variety of modal management systems. The San Diego region envisions the use of these IMTMS informational inputs to create a DSS based on increased sharing of data among corridor agencies. The DSS represents a higher level of decision-making that translates into actionable control strategies, in response to different operational scenarios on the corridor. Figure 3-8 depicts the conceptual monitoring and control strategies, along with the data elements needed to support these strategies. In addition, this figure presents the IMTMS system as an informational exchange utility that interfaces with a variety of decision-making layers.

Figure 3-7. ICMS Operational Concept



[Source: ICMS System-Subsystem Architecture. SANDAG.]

Figure 3-8. Sample DSS



[Source: Sample DSS.]

The I-15 Concept of Operations (ConOps) report lists the following scenarios for the ICM systems that would need to be supported by the DSS:

1. Daily Operations;
2. Freeway Incident;
3. Arterial Incident;
4. Transit Incident;
5. Special Event; and
6. Disaster Response.

These scenarios relate to incidents in different parts of the multimodal system. The detailed information on the scenarios, timelines, and agency responsibilities can be found in the ConOps report. The interpretations of each of these scenarios for the purpose of AMS are:

- **Daily Operations –** No incident scenario for projected 2012 demands (future baseline) and optimized for operations using the different ICM strategies. The scenario will include a combination of ICM strategies meant to improve daily operations.
- **Freeway Incident –** One major freeway incident simulated at a central location of the general purpose lanes on I-15 corridor. A major incident will lead to closure of a number of lanes on the segment. From year 2001 to 2006, the number of major freeway incidents on the I-15 southbound section increased from 164 to 244. Major incidents have been classified as those that cause multiple lane closures. The spike in crashes is attributable to construction activity that has been consistently going on in the corridor. The frequency of these incidents is determined by using AADTs. The estimated AADT for the I-15 South corridor in 2005 was 225,657. Based on this number and the number of major incidents on the southbound corridor in 2005 (242), the Initial Crash Rate (ICR) is determined to be 2.94.
- **Arterial Incident –** One major arterial incident simulated at a central location of one of the arterials in the I-15 study area. A major incident will lead to arterial closure for the segment. The frequency of arterial incidents will be determined based on data that is being acquired from studies in District 11. Currently, these data are available on major arterials in the study area, including Pomerado Road – North and South, Black Mountain Road, and Centre City Parkway. The ICR for Pomerado Road in Poway was 1.15 from 2005 to 2008. The directional ADT estimates for the same time period were 30,700. This information will be used to estimate the frequencies of arterial crashes for 2012 future baseline using travel demand forecasts for ADTs.
- **Transit Incident –** An incident simulated on one of the key alternative modes along the I-15 corridor. A transit incident is assumed to cause significant delays along the transit route. Incident frequencies on transit routes will be calculated from the detailed transit incident information available on the routes included in the study area.
- **Special Event –** A planned special event simulated by increasing trips to and from a particular zone. The number of trips being simulated will be determined by the event chosen to be represented (examples include the Miramar air show or San Diego Chargers games). The frequencies of such scenarios will be estimated based on regionally scheduled events for the year 2008 and the same number will be assumed for 2012.
- **Disaster Response Scenario –** This scenario includes wild and urban interface fire assumed to cause shutdown of specific facilities. The Cedar Fire of October 2003 is used as a blueprint to close facilities that were affected during the fire. The regular demand is

suppressed to create an evacuation scenario. This will be assumed to be a once in several years scenario, and the frequency will be estimated as just when using it to monetize impacts.

The priority order defined for the different incident scenarios is thus:

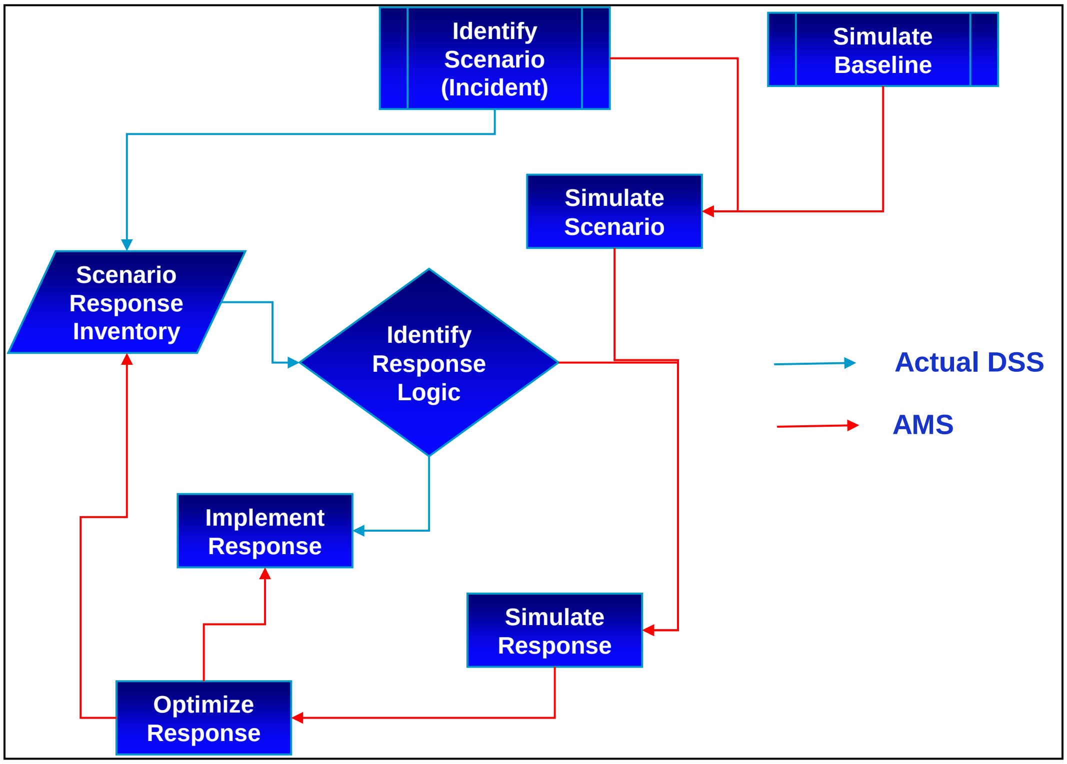
- Freeway Incident;
- Arterial Incident; and
- Special Event/Transit Incident/Disaster Response.

The development of a DSS for any of these scenarios involves the development of a decision logic that combines different response measures, which can be implemented once a particular scenario has been identified to have occurred. The decision logic would consist of the implementation of centrally controlled measures like Ramp Metering, Signal Optimization, En-Route Diversion Information, etc., in a certain sequence. The AMS would focus on implementation of four sample decision logics, representing the DSS, within the simulation to develop different responses to different scenarios. The framework developed to test the DSS would become part of the inventory that considers all possible conditions and also consists of the optimal response strategy which would be the basis of the DSS.

Figure 3-9 shows the assimilation of the simulation process into the DSS. The knowledge-based DSS can be enhanced by including scenarios through model runs. The DSS can also be simultaneously driven by simulation as new events occur. The simulation model plays the key role of optimizing the output (response) from the DSS.

Each of the DSS scenarios that are included in the AMS for evaluation will be compared with a scenario without DSS. For the purpose of the analyses, this scenario refers to the Future Baseline scenario that will include the systems that are planned to be operational on the roadway by 2012. The Future Baseline scenario and non-DSS scenarios would also be induced with an identical incident scenario; however, the systems will not operate under a DSS-based response, but will continue to function with whatever feedback is programmed for 2012. The incident also will be identified by taking into account the maximum clearance time to allow the simulation to run through without gridlock (e.g., incident is cleared within 45 minutes). This control case without DSS is intended to show the incident impact to the system with all the programmed changes in place in order to isolate the effective impact of a DSS-based smart response. The I-15 corridor already will have a lot of the components of system management in place by 2012; however, the benefits of integrating these components are of interest as part of this AMS effort. The non-DSS scenario will, therefore, have the IMTMS (green part in Figure 3-7) architecture that is scheduled to be deployed by 2012, but will not include the DSS subsystem (Red Part in Figure 3-7) that in effect coordinates the operations of different components of the IMTMS.

Figure 3-9. Simulation as Part of DSS Response



[Source: Future Decision Support System (conceptual). SANDAG.]

Table 3-5 provides a list of the different scenarios that are potentially going to be evaluated as part of the AMS effort. The table presents each scenario number along with the analysis settings for demand levels and probability assigned to each scenario. The high demand refers to 102 percent of the typical demand (which is classified as median (medium) demand for purpose of this analysis), and low demand refers to 75 percent of the typical demand. This classification is different than the binning process in order to have a significant number of vehicles on the network for all levels of demand. The next section provides an overview of the ICM strategies that can be considered as part of the DSS. The AMS scenarios identified in Table 3-5 represent the different combinations of these strategies implemented as part of the DSS in response to the incident or no incident scenarios. The corresponding probabilities have been derived from the occurrence of these conditions during regular annual operations, as was identified in Tables 3-3 and 3-4.

Table 3-5. Scenarios for AMS

Scenario	Year	Demand Class	Incident	DSS Operational	Probability (Percentage)
Baseline	2003	Typical Day	None	No	–
A	2012	High	None	No	35%
B	2012	Medium	None	No	6%
C	2012	Low	None	No	32%
D	2012	High	Freeway	No	10%
E	2012	Medium	Freeway	No	2%
F	2012	Low	Freeway	No	11%
G	2012	High	Freeway	Yes	10%
H	2012	Medium	Freeway	Yes	2%
I	2012	Low	Freeway	Yes	11%
J	2012	High	Arterial	No	TBD
K	2012	Medium	Arterial	No	TBD
L	2012	Low	Arterial	No	TBD
M	2012	High	Arterial	Yes	TBD
N	2012	Medium	Arterial	Yes	TBD
O	2012	Low	Arterial	Yes	TBD

3.2 ICM Strategies

Travelers can have multiple responses to congestion and mitigation ICM strategies: route diversion, temporal diversion, mode change, changing travel destination, or canceling their trip are some of these possible traveler responses. The I-15 Corridor will have a number of ICM strategies in operation in the near future. The base year chosen for analysis is 2003, as the most relevant time where no significant construction activity was ongoing on the corridor, and for which there is a validated travel demand model. The number of projects under construction on the corridor makes it imperative that a future baseline scenario be included in the analysis with all these design changes incorporated. This would serve as the Future Baseline scenario, and will be used as the basis of comparison for all the ICM strategies being tested. The Future Baseline scenario will be modeled using information on the 2012 configuration of the roadway available as of December 2008, and will utilize projected 2012 travel demand.

The number of ICM strategies considered for the I-15 corridor has made it necessary to analyze only one peak period in order to stay within the time and budget constraints. The analysis is, however, being developed so that a different set of peak-period conditions can also be developed if such resources become available.

An analysis of a typical peak-day demand during the A.M. and P.M. peak periods for the corridor indicated higher Vehicle Miles Traveled (VMT) in the southbound direction in A.M. peak period than the VMT in the northbound direction during the P.M. peak. The A.M. peak period might be a more useful modeling option, as it represents a higher traffic volume on the HOT lanes and a narrower window of time for time of departure choice, which effect could be captured effectively within the simulation model.

A number of ICM strategies, like Dynamic Pricing and Managed Lanes, will be incorporated into the Future Year Baseline scenario to account for development currently being undertaken on the I-15 corridor. SANDAG provided a list of prioritized ICM strategies that are shown in detail in Appendix A. The following ICM strategies were initially identified as primary test strategies.

- Pre-Trip Traveler Information;
- En-Route Traveler Information;
- Signal Priority for Transit;
- Freeway Ramp Metering;
- Signal Coordination on Arterials with Freeway Ramp Metering;
- Physical Bus Priority;
- Increased HOV Occupancy Requirements; and
- Congestion Pricing on Managed Lanes.

These strategies are discussed in further detail in the ensuing sections. Their exact nature will be finalized based on discussions with SANDAG and U.S. DOT; and on the availability of related information, data, and the necessary resources to complete the work.

Pre-Trip Traveler Information

Pre-trip traveler information includes any travel information accessible to the public that can be used in planning trip routes, estimating departure times, and/or choosing travel mode. Such information can be available through the 511 system, via the phone, the Internet, or public access television. The analysis will capture the impacts of such information on traveler's route choice, departure times, and/or choice of travel mode. The fraction of I-15 users, who access such information prior to making their trip, will be estimated based on data sources available in the region, such as available information on utilization of features like 511 and traffic web sites in San Diego. Subsequently, this portion of the driving population, the "informed drivers," will be identified as a particular driver class within the model. In order to effectively analyze this strategy, the methodology to model mode shifts, as described in Section 2-1, will be utilized. This methodology utilizes the trip tables from the travel demand model, and travel times estimated by simulation models to create a feedback loop for estimation of mode choice. In addition to trip tables, the model will utilize historical travel time estimates on major routes as basis of initial traffic assignment.

En-Route Traveler Information

Initial discussions with U.S. DOT and SANDAG have revealed that there is a need to model the impact of en-route information available to drivers to assess two major issues: 1) change in route choice, and 2) change in mode en-route.

Change in Route Choice

This relates to real-time change in route choice of drivers based on travel time or congestion updates they receive via radio, 511, or wireless-equipped Personal Digital Assistant (PDA) or GPS devices. This feature will be incorporated in the analysis as a fixed percentage of drivers who would be likely to have this information (e.g., sample set of PDA/GPS users or number of 511 users), along with a corresponding “compliance ratio.”

The current information available through the San Diego 511 system deals exclusively with usage statistics. San Diego 511 has been operational since February 2007. The number of requests for I-15 traffic information for 2007 and 2008 were 73,168 and 65,669, respectively. This is the extent of the 511 information available dealing with I-15. No user survey has yet been conducted. Current estimates of GPS penetration by Consumer Electronics Association (CEA) shows that 20 percent of the households in the United States own portable GPS units. An additional nine percent of the households have cars with in-built GPS units. These numbers currently point to a heavy penetration of the GPS units and the numbers are expected to rise significantly in the future. The current technology does support the real-time update of the GPS units to current roads traffic conditions – a subscription service which not all GPS units have. Future efforts might make GPS unit information more active, and create some well-informed drivers that are always being updated of their route choices all the way to their destinations. Based on the current information available, it will be assumed that the GPS market penetration between 2008 and 2012 will not rise drastically, and it can be assumed 30 percent of the population will be able to use the traffic diversion information through in-vehicle information systems. These drivers will be assumed to trust the information on the device so that the reported travel times from the device becomes their perceived travel time.

In TransModeler, a certain percentage of drivers, who have the ability to access such information, will be placed under a particular driver class. At the onset of a particular incident, a macro will be activated to update the route choices of drivers falling within this class. The percentage of drivers who will stay on their original route, divert their route, or change modes will be based upon the level of diversion stemming from the probabilistic route choice model within TransModeler. The compliance rates and the amount of route diversion that occurs will also vary based on the type of scenario being modeled. This driver type will be part of the multiple categories of drivers that will be able to view the information on variable message signs, and base their mode choice decisions on the logit model mentioned in Section 2. This means that an informed driver will be able to change route or mode based on the availability of information, and the percentage that do will be based on the traffic conditions and every driver’s value of time (which will be distributed randomly for the entire driver population).

To facilitate, modeling sensors can be placed along the route upstream of the message sign. As drivers approach the message sign, they will pass through these sensors, which in turn will call up a macro that will update these drivers’ route choice decisions. When the macro is activated, new routes will be assigned to the percentage of drivers that divert their routes based on the posted information. Depending on the scenario or type of incident that may have occurred, compliance rates associated with each message sign will vary, and hence the amount of route diversion also will differ throughout the simulation runtime.

Change in Mode En-Route

This is a real possibility on the I-15 corridor considering that BRT is being introduced along the corridor, and there will be direct access to "Bus Transit Hubs" from HOT lanes, as well as from General Purpose lanes. This mode shift will be analyzed by evaluating a fixed number of options for a certain percentage of drivers as they approach a Transit Hub. The methodology described for changes in route choice is fairly similar to how the model addresses drivers' reactions, as they approach a message sign near a transit hub exit. In this situation, a macro can be used to update drivers' route choice decisions as they near the hub. Drivers at this point will have the option of staying on their original route; diverting to a different path (i.e., choose the HOT lanes if they are on the General Purpose Lanes); or change their destination by shifting to a different mode (i.e., BRT). Similar to the variable message sign, depending on the parking availability at the transit hub or the conditions on either the General Purpose or the HOT lanes, compliance rates can be set to assign a certain percentage of drivers to shift modes, and the percentage of drivers diverting will be based on a nested logit-based decision model. The distinction between compliance and diversion is important in this context. Compliance indicates a willingness of drivers to utilize the information provided to them, and diversion counts only those drivers that actually shift a mode or route based on this compliance percentage.

Signal Priority for Transit

A key objective of this ICM strategy is to improve transit efficiency and service. In order to determine the impacts of transit signal priority on the corridor, existing transit networks, and routes suitable for priority will be identified in discussions with SANDAG and U.S. DOT. In addition, any existing routes with transit signal priority implemented also will be incorporated into the model. The signal priority will be implemented by simulating activation and deactivation sensors that are assigned different priority classes in order to trigger calls to request, or to terminate, signal priority. TransModeler has the capability to model Transit Signal Priority through the signal development interface itself. Any innovations from SANDAG's QuicNet framework will be applied in the analysis.

Ramp Metering

The I-15 freeway currently has a number of ramps that are metered in both the northbound and southbound directions. The meters operate on a local occupancy-based algorithm working off the San Diego Ramp Metering Software (SDRMS). One of the future scenarios includes the conversion of Ramp Metering algorithm from locally-adaptive to systemwide-coordinated. The analysis will test a systemwide coordinated ramp metering algorithm implemented under the IMTMS framework. The current ramp metering algorithms implemented in the corridor will be incorporated into the TransModeler utilizing the GIS – Development Kit (DK) framework. The decision to utilize a different ramp metering strategy in the future will be made in discussions with SANDAG based on planned improvements in the corridor for future baseline. Any upgrades to the ramp metering strategy will be programmed into TransModeler.

Alternative ramp metering algorithms, as well as new signal timing plans, can be created and customized to fit a particular incident scenario. In TransModeler, when the incident occurs, the appropriate set of metering strategies and signal timing plans can be called up to replace the existing signal and metering operation in order to address the present traffic conditions. The ramp metering algorithm and signal timing plans used will also vary based on the signal coordination plan set to address the particular incident scenario (addressed in the next section on signal coordination).

Signal Coordination on Arterials with Freeway Ramp Metering

In addition to simulating Signal Coordination on Arterials, which involves implementing the QuicNet traffic signal control platform within the simulation model, the ramp metering algorithms will be introduced within this framework to evaluate the best possible strategy to optimize operations on both the freeway and the arterials. The Ramp Metering strategy will be coordinated with the signal timing set-up on the arterials, and the performance of both the corridor and impacted roadway network will be evaluated based on input from the QuicNet system.

Physical Bus Priority

Similar to transit signal priority, physical bus priority improvements on the arterials and freeways have the ability to improve transit service within the corridor. Additionally, these strategies also can prevent transit vehicles from crossing paths with other movements and alleviate the presence of existing difficult maneuvers. In order to model this strategy, bus routes and arterials suitable for such strategies will be identified in discussions with SANDAG and U.S. DOT. Bus priority will be implemented along the I-15 HOT lanes to include exclusive bus lanes and ramps.

Increased HOV Occupancy Requirements

The analysis will evaluate the impacts of this strategy by testing different HOV occupancy requirements on the managed lanes (2+ to 3+, etc.). The increased occupancy requirements will be evaluated both in terms of vehicle-throughput and person-throughput. The potential impacts of such requirements on revenue-based scenarios can be evaluated in the Combination strategy (along with Congestion Pricing on Managed Lanes, see below). As the 2012 model will comply with the increased HOV occupancy requirements, this impact will be captured during the trip estimation process as an input to the microsimulation.

Congestion Pricing on Managed Lanes

Currently, I-15 managed lanes are set to use dynamic pricing, setting toll rates based on the changing level of traffic congestion. The impacts of different levels of congestion on toll prices and subsequently on traffic management on the corridor will be evaluated in this scenario. The congestion pricing scenario will be evaluated based on planned pricing scenarios to be provided by SANDAG.

3.3 Analysis Settings

Table 3-6 summarizes the analysis settings for the I-15 Corridor.

All analysis scenarios will be compared against a Future Baseline scenario. The main difference between the Future Baseline and the different scenarios being evaluated is that the future baseline model will introduce the different ICM strategies in an uncoordinated approach. In contrast, the different alternative scenarios will make use of a Decision Support System to take advantage of coordination benefits between different ICM strategies. The exact nature of the Decision Support System is still being finalized by SANDAG, and will be provided prior to completion of the Future Baseline scenarios.

Table 3-6. San Diego I-15 Corridor

Summary of Analysis Settings

Parameter	Value	Comment
Base year	2003	The base analysis year is based on the available validated model year in the regional travel demand model.
Analysis year	2012	The analysis year is derived from the anticipated finishing of construction of system, and implementation of ICM Strategies.
Time period of Analysis	A.M.	The analysis of the A.M. peak period provides the most benefit in terms of assessing the proposed ICM strategies.
Simulation Period	3-6 hours	6 a.m.-9 p.m. is the primary analysis period. Future baseline scenarios will run for longer to calculate performance metrics.
Freeway Incident Location	South of Rancho Bernardo	Based on analysis conducted as part of V/C determination this location experiences high number of incidents. This location also offers the potential for route diversions and has high impacts on corridor travel.
Arterial Incident Location	TBD	This will depend on 2012 demand projections to calculate ICR's for different arterials under study.
Incident Duration	45 minutes	Lack of reliable data on incident duration means this length is chosen to represent a major blockage in the peak period.

The following is a summary of the response strategies for each of the scenarios, as determined by SANDAG. The list shows the scenario with the corresponding strategies that will be modeled depending on availability of resources. Table 3-7 following the strategies lists the set of assumptions for pre-/post-ICM implementation assumptions.

- Daily Operations:
  - Pre-Trip and En-Route Traveler Information;
  - Transit Signal Priority;
  - Ramp-Metering and Arterial Signal Coordination;
  - BRT; and
  - Congestion Pricing for ML.
- Freeway Incident:
  - Pre-Trip and En-Route Traveler Information;
  - Transit Signal Priority;
  - Ramp-Metering and Arterial Signal Coordination;
  - BRT; and

  - Congestion Pricing for ML.

- Arterial Incident:
  - Pre-Trip and En-Route Traveler Information;
  - Transit Signal Priority; and
  - Ramp-Metering and Arterial Signal Coordination.

- Transit Incident:
  - Pre-Trip and En-Route Traveler Information;
  - Transit Signal Priority; and
  - Ramp-Metering and Arterial Signal Coordination.

- Special Event:
  - Pre-Trip and En-Route Traveler Information;
  - Transit Signal Priority;
  - Ramp-Metering and Arterial Signal Coordination;
  - BRT; and
  - Congestion Pricing for ML.

Table 3-7. Model Assumptions/Inputs

Outcome of Strategies	Summary/Notes to Modeling Team	Post-ICM	Pre-ICM in Place
1. En-Route Information			
1.1 Earlier Dissemination of En-Route Incident and TT 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.	10 minutes to dissemination.	• Two minutes to dissemination. • 3% of travelers will defer the trip to later or cancel. • 30% of Traffic (GPS, 511, radio combined) with near perfect information. • Traffic will spread to other routes and modes.
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 TT.	The travelers will make diversion choices at equal intervals of time (for the next time period). The decision choice will be 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			

Outcome of Strategies	Summary/Notes to Modeling Team	Post-ICM	Pre-ICM in Place
2.1 Incident Signal Retiming Plans	San Diego will develop '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.	30-60 minutes to implement.	• Based on Location in Primer on Signal Coordination provided. • Assumption – 10 minutes to implement (variable based on severity). • Higher throughput. • Off-ramp and diversion planning.

Outcome of Strategies	Summary/Notes to Modeling Team	Post-ICM	Pre-ICM in Place
2.2 Freeway Ramp Metering Plans	By using predesignated Freeway and Major Arterial closure points at intersections with freeways or major roads, this will avoid travelers being forced to exit at the last available exit point and entering a local road that causes more delay. The effects will be less delays to travelers forced to exit at closures, and less congestion on local arterials.	30 minutes to deploy closures.	<10 minutes to deploy planned closure points. "Aware" drivers will be disseminated information early enough before they approach congestion/incident location.
2.3 Freeway Ramp Metering and Signal Coordination	Incident Location-based strategy to coordinate 2.1 and 2.2 above.	None.	2.1 and 2.2 coordination under RAMS framework.
2.4 HOT Lanes	Existing today; should be 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			
3.4 Transit Signal Priority (TSP)	Transit Signal Priority for BRT and buses will be developed by SANDAG in coordination with the cities.	No TSP.	Near real-time TSP for transit and physical bus priority.
4. Reduced Incident Times			

Outcome of Strategies	Summary/Notes to Modeling Team	Post-ICM	Pre-ICM in Place
4.1 Reduced Time of Detection, Notification, and Verification of Incidents	Traffic Incident Management currently 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 decision making process and delegation of authority/responsibility of actions will reduce response times.	All agencies notified within 30-60 minutes. Incident Clearance in < 90 minutes (CHP and Caltrans 90-minute incident response/ clearance performance measure).	All agencies notified within 5 minutes. I-15 Managed Lanes and Traffic Incident Management Plans provides a blue print for coordination, but no set times, so this is an assumption.

Chapter 4 Performance Measures

This section provides an overview of the performance measures that will be used in the evaluation of ICM strategies for the I-15 Corridor. To be able to compare different investments within a corridor, a consistent set of performance measures will be applied. These performance measures will:

- Provide an understanding of traffic conditions in the study area;
- Demonstrate the ability of ICM strategies to improve corridor mobility, throughput, reliability, and safety based on current and future conditions; and
- Help prioritize individual investments or investment packages within the Test Corridor for short- and long-term implementation.

To the extent possible, the measures will 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.
- The performance measures will focus on the following four key areas:
  1. **Mobility –** Describes how well the corridor moves people and freight;
  2. **Reliability –** Captures the relative predictability of the public's travel time;
  3. **Safety –** Captures the safety characteristics in the corridor, including crashes (fatality, injury, and property damage); and
  4. **Emissions and Fuel Consumption –** Captures the impact on emissions and fuel consumption.

4.1 Mobility

Mobility describes how well the corridor moves people and freight. The mobility performance measures are readily forecast. Three primary types of measures will be used to quantify mobility in the I-15 Corridor, including the following:

1. **Travel time –** This is defined as the average travel time for the entire length of the corridor or segment within a study corridor by facility type (e.g., mainline, HOV, and local street) and by direction of travel. Travel times will be computed for the peak period.
2. **Delay –** This is defined as the total observed travel time less the travel time under un-congested conditions, and will be reported both in terms of vehicle-hours and person-hours of delay. Delays will be calculated for freeway mainline and HOV facilities, transit, and surface streets.
3. **Throughput –** Throughput will be measured by comparing the total number of vehicles entering the network and reaching their destination within the simulation time period. The measure will ensure that the throughput of the entire system can be utilized as a performance

measure for all the scenarios. The corresponding VMT, PMT, Vehicle Hours Traveled (VHT), and Person Hours Traveled (PHT) will be reported as a macroscopic measure of the general mobility of the corridor.

4.2 Reliability and Variability of Travel Time

Reliability and Variability capture the relative predictability of the public's travel time. Unlike mobility, which measures how many people are moving at what rate, the reliability/variability measures focus on how much mobility varies from day to day. For the I-15 Corridor, travel time reliability/variability will be calculated using the simulation models by performing multiple model runs for all scenarios. Appendix C describes the methodology used in calculating reliability and variability impacts.

4.3 Safety

For the safety performance measure, the number of accidents and accident rates from accident databases will be used for the I-394 Corridor. The annual safety benefits will be calculated using incident frequencies from the freeways and any arterial and transit incident information available. Although the PeMS database includes some of the freeway incident information, the arterial and transit information may not be available.

4.4 Emissions and Fuel Consumption

The I-15 Corridor AMS also will produce estimates of emissions and fuel consumption, associated with the deployment of ICM strategies based on the methodology applied in the Test Corridor AMS. The Test Corridor AMS utilized the IDAS methodology, which incorporates reference values to identify the emissions and fuel consumption rates based on variables such as facility type, vehicle mix, and travel speed. The emissions and fuel consumption rates will be based on currently available sources such as California Air Resources Board EMFAC. Emissions will be computed by pollutant, mode, and facility type. Fuel consumption will be computed by fuel type, mode, and facility type.

4.5 Cost Estimation

For the identified ICM strategies, planning-level cost estimates will be prepared, including life-cycle costs (capital, operating, and maintenance costs). Costs will be expressed in terms of the net present value of various components and are defined as follows:

- **Capital Costs –** Includes up-front costs necessary to procure and install ITS 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, the costs are further disaggregated to show the infrastructure and incremental costs. These are defined as follows:

- **Infrastructure Costs –** Include the basic “backbone” infrastructure equipment necessary to enable the system. For example, in order to deploy a camera (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.

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

The costs will be estimated for each scenario and a benefit cost ratio assigned to all the individual performance measures. The annualized benefits for each of the measures mentioned above will be calculated using incident frequencies from the freeways and any arterial and transit incident information available. The methodology for calculating these frequencies is provided in Section 3.1.

Chapter 5 Model Calibration

Accurate calibration is a necessary step for proper simulation modeling. Before modeling ICM strategies, model calibration ensures that base scenarios represent reality, creating confidence in the scenario comparison.

5.1 Simulation Model Calibration

Each simulation software program has a set of user-adjustable parameters that enable the practitioner to calibrate the software to better match specific local conditions. 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 "un-modeled" site-specific factors through the adjustment of the calibration parameters 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 accurately reproduce local traffic conditions. The key issues 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.

5.2 Calibration Approach

Available data on bottleneck locations, traffic flows, and travel times will be used for calibrating the simulation model for the analysis of the Pioneer Corridor. The I-15 Corridor calibration strategy will be based on the three-step strategy recommended in the FHWA Guidelines for Applying Traffic Microsimulation Modeling Software:[4]

1. **Capacity calibration –** An initial calibration performed to identify the values for the capacity adjustment parameters that cause the model to best reproduce observed traffic capacities in the field. A global calibration is performed first, followed by link-specific fine-tuning. The

[4] 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.

Capacity calibration will be done utilizing volume data collected from the PeMS database for the year 2003 between the periods of September to November.

2. **Route choice calibration –** The Pioneer Corridor will have parallel arterial streets, making route choice calibration important. A second calibration process will be performed with the route choice parameters. A global calibration is performed first, followed by link-specific fine-tuning.
3. **System performance calibration –** Finally, the overall model estimates of system performance (travel times and queues) will be compared to the field measurements for travel times and queues. Fine-tuning adjustments are made to enable the model to better match the field measurements.

Calibration Criteria

The calibration criteria presented in Table 5-1 will be applied for the Pioneer Corridor simulation, subject to the budget and schedule constraints for the Pioneer Corridor AMS.

Table 5-1. Calibration Criteria for the Pioneer Corridor AMS

Calibration Criteria and Measures	Calibration Acceptance Targets
• Traffic flows within 15% of observed volumes for links with peak-period volumes greater than 2,000	• For 85% of cases for links with peak-period volumes greater than 2,000
• 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
• Visual Audits *Bottlenecks: Visually Acceptable Queuing*	• To analyst's satisfaction

5.3 Model Calibration Data Requirements

The model calibration methodology outlined in Sections 5-1 and 5-2 requires a diversified set of data, including the following:

- Traffic flows at individual links, as well as on screen-lines across the arterial, freeway and transit components of the ICM Corridor;
- Travel times along critical segments of the ICM Corridor freeway and arterial components;
- O-D surveys, if available, identifying travel patterns along the freeway and arterial components of the ICM Corridor; and
- Any available bottleneck observations along critical segments of the ICM Corridor freeway and arterial components.

In addition to this information, for the I-15 Corridor in San Diego, the following data requirements have been identified for model calibration purposes, as well as for building and verifying future base line and alternative models:

- PeMS data for base year 2003 (Appendix B shows the existing coverage);
- Traffic studies within the defined study area for year 2003 (counts and travel times);
- Truck percentages on corridor;
- Arterial Signal Timings and Ramp metering algorithms;
- Signal optimization with QuicNet Framework – Logic and Synchro Files; and
- Queuing/bottleneck graphs included in ConOps for year 2003 (current ConOps graphs are based on 2006/2007 data).

Chapter 6 Documentation

The methodologies, tools, and results of the Pioneer Corridor will be documented in a report that will be organized as follows:

- **Chapter 1.0** will outline the principles guiding the development and application of ICM AMS;
- **Chapter 2.0** will present the AMS methodology, and will provide a summary of the Pioneer Corridor site;
- **Chapter 3.0** will present the structure for the Pioneer Corridor analysis approach, performance measures, how to take into account nonrecurrent congestion, and ICM strategies and analysis alternatives applied for the Pioneer Corridor AMS; and
- **Chapter 4.0** will present the Pioneer Corridor AMS results, as well as conclusions and lessons-learned.

Chapter 7 Schedule and Allocation of Responsibilities

The activities identified in this Analysis Plan are envisioned to be completed within a 15-month time period. Table 7-1 summarizes the labor-hours required by the different involved parties and provides an allocation of responsibilities across these parties.

Table 7-1. Labor and Allocation of Responsibilities

Task	Sub-Task	Deliverable	Responsibility
Data Collation and Reduction			
	Obtain Arterials Traffic Data	Existing Traffic Data	Alex Estrella/Mark Miller
	Obtain Signal Timings and Aerials	Traffic Signal Timings/Aerials/RM Info	Alex Estrella
	Download PemS Data	PemS Analysis Memo	Dorothy Morall/Albinder Dhindsa
	Determine Typical Conditions	Typical Day Selection Methodology	Albinder Dhindsa
	Balanced Traffic Counts	Finalized Balanced Volumes	Dorothy Morallos/Eleni Christofa
	Travel Time/Bottleneck Preparation	Finalized Calibration Data	Dorothy Morallos/SANDAG Analyst
Model Preparation			
	Network Coding	Transcad Model Prep	Mike Calandra
	Coding Signal Timings and RM	Transmodeler Prep	Christopher Teolis/SANDAG Analyst
	QA/QC		John Lewis
Calibration			
	Estimation of Initial OD Matrix	Initial OD Matrix	Mike Calandra
	Refining OD Zones	Iterative ODs	Mike Calandra/SANDAG Analyst/John Lewis
	Model Calibration	Data Preparation for Calibration	Dorothy Morallos/Ilgin Guler/SANDAG Analyst
	Validation	Final Model	Albinder Dhindsa
	Review and QA	Review and QA	John Lewis
Preparation of Future Baseline			
	Network Coding	Transcad Model Prep	Mike Calandra/SANDAG Analyst
	Demand Preparation	OD Matrices for Future Baseline	Mike Calandra/SANDAG Analyst/John Lewis
	Verification	Transmodeler Modeling	Christopher Teolis/Eleni Christofa/Ilgin Guler
Alternative Analysis (Inc. Demand Estimations)			
	Alternative A		
		Transcad Model Prep	Mike Calandra/SANDAG Analyst
		OD Matrices for Alternative	Mike Calandra/SANDAG Analyst
		Transmodeler Modeling	Christopher Teolis/Eleni Christofa/Ilgin Guler
	Alternative B		
		Transcad Model Prep	Mike Calandra/SANDAG Analyst
		OD Matrices for Alternative	Mike Calandra/SANDAG Analyst
		Transmodeler Modeling	Christopher Teolis/Eleni Christofa/Ilgin Guler
	Alternative C		
		Transcad Model Prep	Mike Calandra/SANDAG Analyst
		OD Matrices for Alternative	Mike Calandra/SANDAG Analyst
		Transmodeler Modeling	Christopher Teolis/Eleni Christofa/Ilgin Guler
	Alternative D		
		Transcad Model Prep	Mike Calandra/SANDAG Analyst
		OD Matrices for Alternative	Mike Calandra/SANDAG Analyst

Task	Sub-Task	Deliverable	Responsibility
		Transmodeler Modeling	Christopher Teolis/Eleni Christofa/Ilgin Guler
	Review and QA/QC		
Reporting and Documentation			
	Calibration Summary Document		Albinder Dhindsa
	Modeling Report		Christopher Teolis/Albinder Dhindsa
	Draft AMS Document		Albinder Dhindsa
	Review and Comments		Alex Estrella/Mark Miller/Vassili Alexiadis
	Final AMS Document		Albinder Dhindsa

APPENDIX A. Summary of San Diego I-15 ICM Strategies

The following table summarizes the ICM strategies for the San Diego I-15 ICM Stage II (AMS) Project based on the ConOps from Stage I, together with notes to the AMS modeling team.

Table A-1. Prioritized List of Strategies

Strategies	Notes to AMS Modeling Team	High – Definitely needs to be modeled Medium – Borderline may not need modeling Low – Does not need modeling	Scenario					
			Daily	Freeway Incident	Arterial Incident	Transit Incident	Special Event (Planned)	Disaster Response
1. Share/Distribute Information								
1.1 Pre-trip traveler information	Information will be provided to the public via the 511 system (telephone, Internet) and the public access TV system. People will be able to decide whether to take their trip as originally planned or change departure time, trip route, and/or travel mode.	High	X	X	X	X	X	X
1.2 En-route traveler information	Information will be provided to the public via multiple media including changeable message signs (CMSs), Next Bus informational sign displays at bus stops/stations, phone, and PDA/Blackberry. This information will allow travelers to potentially change mode, alter route or departure time.	High	X	X	X	X	X	X
2. Junctions/Interfaces Improvement								
2.1 Signal pre-emption	Because of the urgent need to accommodate emergency vehicles, signal preemption has been a standard practice for a long time. This strategy helps identify the “best route” for emergency vehicles during incidents and response to emergency situations/disasters.	Low			X	X		X

Strategies	Notes to AMS Modeling Team	High – Definitely needs to be modeled Medium – Borderline may not need modeling Low – Does not need modeling	Scenario					
			Daily	Freeway Incident	Arterial Incident	Transit Incident	Special Event (Planned)	Disaster Response
2.2 Multimodal electronic payment	This is SANDAG's Universal Transportation Account (UTA) that will make it convenient for travelers to make intermodal trips. It will begin with a regional automated fare collection system, which will deploy a smart card-based fare collection network throughout San Diego County and initially used for transit. The UTA will combine elements so that the same electronic toll collection tag/smart card can be used to pay transit fares, tolls, and parking for added convenience.	Medium	X					
2.3 Transit Signal Priority	Transit signal priority on arterials can reduce transit vehicle travel time, improve reliability, and help maintain transit schedule adherence. It is a means of enhancing corridor management across networks. Although to-date transit signal priority has yet to be deployed on arterials in the corridor, it is being implemented on North County Transit District Bus Route 350 (bus feeder for corridor BRT system) with implementation complete in 2008. This is an important addition to the set of I-15 ICMS assets.	High	X				X	
2.4 Ramp meters/arterial traffic signals coordination	At this crucially important junction of the freeway and arterial networks, it is very important to establish and successfully maintain coordinated activities across the networks. Doing so helps achieve ICMS goals of accessibility for corridor travelers to travel options and attain enhanced mobility levels.	High	X	X	X	X	X	X

Strategies	Notes to AMS Modeling Team	High – Definitely needs to be modeled Medium – Borderline may not need modeling Low – Does not need modeling	Scenario					
			Daily	Freeway Incident	Arterial Incident	Transit Incident	Special Event (Planned)	Disaster Response
2.5 BRT	This strategy refers to operational and physical aspects of enhancing transit service, such as queue jumpers, dedicated bus lanes, or access ramps; and decreased headways and other transit-related enhancements anticipated through the implementation of BRT systems along the I-15 corridor.	High	X	X			X	
2.6 Transit hub connection protection	This means holding one transit service while waiting for another transit service to arrive. This strategy is governed by the Regional Transit Management System (RTMS), which currently is operational and supports all fixed-route transit operations for the San Diego Metropolitan Transit System and the North County Transit District; will support other regional transit operators in the future. RTMS allows data-sharing and information exchange, as needed, to promote more efficient regional transit operations and coordination of transit services between operators, such as to coordinate passenger transfers between transit systems.	Low				X	X	
3. Accommodate/Promote Network Shifts								
3.1 Modify ramp metering rates	This strategy will help accommodate traffic, including transit buses that are shifting from arterials.	High	X	X	X	X	X	X

Strategies		Notes to AMS Modeling Team	High – Definitely needs to be modeled Medium – Borderline may not need modeling Low – Does not need modeling	Scenario					
				Daily	Freeway Incident	Arterial Incident	Transit Incident	Special Event (Planned)	Disaster Response
3.2	Promote route and mode shifts	This strategy focuses on shifts between roadways and transit by means of en-route and pre-trip traveler information services.	Medium/High	X	X	X	X	X	
3.3	Congestion pricing for ML	Currently under phased construction; initial segment fully implemented in 2008.	High	X	X	X	X	X	X
3.4	Modify arterial signal timing	This strategy will help accommodate traffic that shifts from the I-15 freeway.	High	X	X	X	X	X	X
4.	**Capacity/Demand Management (Short-Term)**								
4.1	Lane use control	This primarily involves changes to the Managed Lanes lane configuration from default of two lanes per direction to 3/1 or 4/0 split, especially for evacuation purposes during the Disaster Response Scenario.	Low		X			X	X
4.2	Modify HOV restrictions	This focuses on increasing the minimum number of occupants required in HOVs.	High		X				X
4.3	Increase roadway capacity by opening HOV/HOT lanes and shoulders	This has been successfully implemented as a one-year demonstration project allowing buses on shoulders from I-805 and Nobel Drive to SR 52 and Kearny Villa Road during moving and afternoon peak periods. The use of shoulders as a low-speed bypass of congested freeway lanes offers a low-cost, easily implemented strategy that should increase transit operating speeds, on-time performance, and trip reliability.	Medium		X				X

Strategies		Notes to AMS Modeling Team	High – Definitely needs to be modeled Medium – Borderline may not need modeling Low – Does not need modeling	Scenario					
				Daily	Freeway Incident	Arterial Incident	Transit Incident	Special Event (Planned)	Disaster Response
4.4	Temporary addition of transit capacity	This is primarily used during planned special events, though is applicable during incidents and the worst case scenario (Disaster Response).	Low			X		X	X
4.5	Modify parking fees	This refers to the Smart Parking System (SPS) that currently is undergoing a Pilot Test on I-5 in conjunction with the Coaster commuter rail system. SPS uses a variety of technologies to collect real-time parking data and provides this information to transit users. Focus is placed on parking facilities at Bus Rapid Transit stations.	Low	X					
5.	**Capacity/Demand Management (Long Term)**								
5.1	Ride-sharing programs	Can this be modeled given the inherent variability over time in such programs? Can this be viewed alternatively as an incentive for carpooling/HOV?	Medium	X				X	
5.2	Expand transit capacity	This refers to practices such as adding a route or decreasing headway.	Medium				X	X	

APPENDIX B. Data Collection Plan

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 multi-jurisdictional 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 multi-agency 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 Schedule Constraint –** The overall ICM AMS effort must take place within the budget and schedule 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.

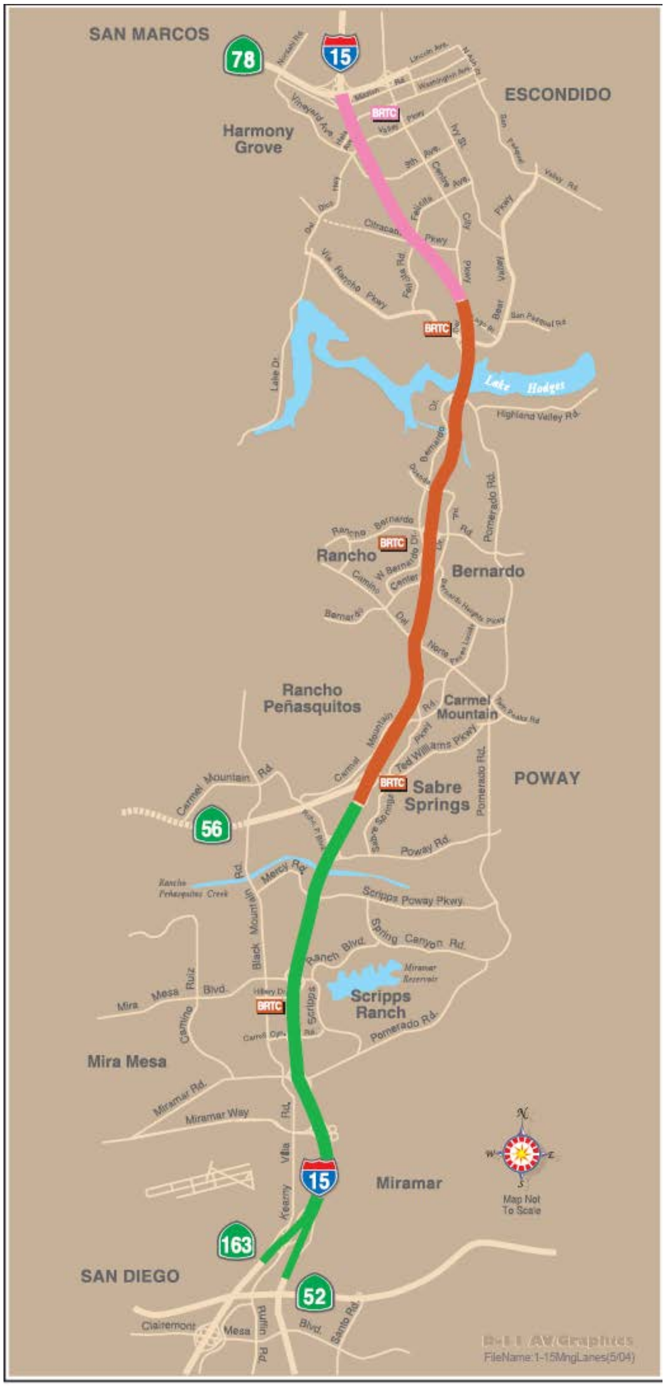
This appendix outlines the AMS Data Collection plan for the I-15 ICM Corridor in San Diego County. The focus of this appendix is on the specific types of data that currently are available, whether in electronic or paper form, including listings of signalized arterial intersections with signal timing 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:

1. Centre City Parkway;
2. Pomerado Road;
3. Rancho Bernardo Road;
4. Camino Del Norte Road;
5. Ted Williams Parkway;
6. Black Mountain Road; and
7. 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.

Figure B-1. Study Area



[Source: SANDAG: AV Graphics.]

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 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.

Methodology for Developing the Data Collection Plan

The methodology for developing the Data Collection Plan comprises a four-step process described as follows:

1. 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:
    a. Integrated Corridor Management – Analysis, Modeling, and Simulation *Sample Data List* draft report, December 2006;
    b. Integrated Corridor Management – Analysis, Modeling, and Simulation for the San Diego I-15 in San Diego, California Analysis Plan, November 2008;
    c. San Diego I-15 Integrated Corridor Management (ICM) System, *Final I-15 ICM Concept of Operations*, March 2008; and
    d. San Diego I-15 Integrated Corridor Management (ICM), *Final I-15 ICM System Requirements,* March 2008.
2. Assess the current state of required data by corridor agency stakeholders, including the following:
    a. SANDAG;
    b. Caltrans;
    c. Cities of San Diego, Escondido, and Poway; and
    d. Metropolitan Transit System and North County Transit District.
3. Identify gaps between data requirements and available data.
4. Develop a specific timeline schedule 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-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, systemwide)*	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*

Network	Travel Demand	Traffic Control	Transit	ITS Elements
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 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 Concept of Operations. The table is configured as a matrix with ICM Approaches and Strategies, together with the AMS Input Data components.

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

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.

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

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
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
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 13^{th}	Y				Y
29	Centre City at 9^{th}	Y				Y
30	Centre City at Citracado	Y	2007, 2004	2004	2007, 2004	Y
31	Centre City at (Felicita) Town Centre Dr./W. 18^{th} 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

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
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
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

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
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

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
81	Pomerado Road at Ted Williams Parkway	Y				Y
82	Pomerado Road at Treadwell	Y				Y
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

No.	Intersection	Signal Timing Plans	Vehicle Through Volumes	Pedestrian Volumes	Turning Movement Counts (TMC)	TMC Request
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

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).

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)

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
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
		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		

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
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
		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

No.	Interchange	Ramps	Type	PeMS Data 2003	PeMS Data 2008
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
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		

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:

1. Premium Express Bus Route 810 – Escondido to Downtown San Diego;
2. Premium Express Bus Route 820 – Poway to Downtown;
3. Premium Express Bus Route 850 – Rancho Peñasquitos to Downtown;
4. Premium Express Bus Route 860 – Rancho Bernardo to Downtown;
5. Express Service Bus Route 20 – Downtown San Diego to North County Fair; and
6. 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 data bases 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.

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

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.

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.

APPENDIX C. Performance Measure Calculation Using Simulation – San Diego I-15

This appendix describes the methodology used in calculating various performance measures for the ICM AMS effort underway for the San Diego I-15 site.

Colleagues who have contributed substantively to this document either conceptually or by identifying needed corrections and clarifications include Meenakshy Vasudevan (Noblis); Vassili Alexiadis, Vassilis Papayannouis, Lin Zhang, and Haining Du (Cambridge Systematics, Inc.); Yi-Chang Chiu (University of Arizona); Khaled Abdelghany, (Southern Methodist University).

Calculation Procedures for Key Integrated Corridor Performance Measures from Simulation Outputs

A core element of the ICM initiative is the identification and refinement of a set of key performance measures. These measures represent both the bottom line for ICM strategy evaluation, and define what "good" looks like among key corridor stakeholders. To date, the emphasis on performance-driven corridor management among the participating Pioneer Sites has been on measures derived from observed data. In the AMS phase of the effort, however, attention has turned to producing comparable measures derived from simulation outputs. This document provides a detailed process by which a set of key national measures of corridor performance can be calculated. It is the intent of the ICM program, and this document, that these processes will be implemented consistently in the three participating AMS sites applying the ICM AMS methodology.

This document 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 document begins with a discussion of the calculation of travel time, which informs both a calculation of delay, as well as travel time reliability. Next, we provide a discussion of how corridor throughput is defined and measured. The document 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.

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.

We record travel time from a single run of the simulation under operational conditions k for this unit of observation as $t_i^k = t_{o,d,\tau',m}^k$.[5] *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 a.m. peak analysis with five 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 OD pair that begin in a particular time window. Let τ represent this interval (e.g., an interval between 6:30 a.m. and 6:45 a.m.) 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, $\bigcup_m \boldsymbol{I}_{o,d,\tau,m}^k = \boldsymbol{I}_{o,d,\tau}^k$ 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 starting 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 also must 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 $k \in K$:

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

[5] 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 in 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 $k \in K$:

$$n_{o,d,\tau,m} = \sum_{k \in K} n^k_{o,d,\tau,m} p_k$$

(Equation 2a)

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

$$T^k_{o,d,\tau} = \frac{\sum_m T^k_{o,d,\tau,m} \, n^k_{o,d,\tau,m}}{n^k_{o,d,\tau}}$$

(Equation 3)

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

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

(Equation 4)

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

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

(Equation 4a)

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

$$T = \frac{\sum_{\forall o,d,\tau} T_{o,d,\tau} \, n_{o,d,\tau}}{\sum_{\forall o,d,\tau} n_{o,d,\tau}}$$

(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,τ level by deriving a zero-delay threshold by mode $T^0_{o,d,\tau,m}$.

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

$$T^0_{o,d,\tau,m} = \min_{k \in K} \left\{ T^k_{o,d,\tau,m} \right.$$

(6)

In some cases, the cluster analysis will group low-demand, nonincident 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 also may 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 generate a large enough number of 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.

Once zero-delay thresholds $T^0_{o,d,\tau,m}$ are identified, average trip delay can be calculated by mode for each o,d,τ,m:

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

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

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

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 already have 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 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:

$$\mathbf{T}_{o,d,\tau} = \left[T^{1}_{o,d,\tau}, T^{2}_{o,d,\tau}, \cdots, T^{J}_{o,d,\tau}\right], \text{ where } T^{j}_{o,d,\tau} \leq T^{j+1}_{o,d,\tau} \text{ for all } j = 1 \cdots J$$

(Equation 11)

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

$$T^{[95]}_{o,d,\tau} = T^{j}_{o,d,\tau} \text{ where } \sum_{k=1}^{j} p_k = 0.95$$

(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 over all conditions $k \in K$:

$$\rho_{o,d,\tau} = \frac{T^{[95]}_{o,d,\tau}}{T^{0}_{o,d,\tau}}$$

(Equation 12)

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

$$\rho = \frac{\sum_{\forall o,d,\tau} \rho_{o,d,\tau}\, n_{o,d,\tau}}{\sum_{\forall o,d,\tau} n_{o,d,\tau}}$$

(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.

For example, variance in travel time among members of the same time interval in a single run is the variance of $t_{o,d,\tau'}$ with respect to $\tau' \in \tau$:

$$V_{o,d,\tau}^{k} = \frac{\sum_{\tau' \in \tau} \left(t_{o,d,\tau'}^{k} - T_{o,d,\tau}^{k} \right)^2}{n_{o,d,\tau}^{k} - 1}$$

(Equation 14)

If we seek to identify the variance in conditions that are reflective of a traveler making the same trip at roughly the same time on a regular basis, however, our unit of observation is the o,d,τ trip-making window with respect to $k \in K$. In this case, the calculation of variance also includes the consideration of the probabilities of each operational condition.[6]

$$V_{o,d,\tau} = \sum_{k \in K} \left(T_{o,d,\tau}^{k} - T_{o,d,\tau} \right)^2 p_k$$

(Equation 14a)

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

$$V = \frac{\sum_{\forall o,d,\tau} V_{o,d,\tau}\, n_{o,d,\tau}}{\sum_{\forall o,d,\tau} n_{o,d,\tau}}$$

(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 systemwide 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.

---

[6] We make a simplifying assumption that the unbiased variance is well approximated by the biased variance in this case; that is, we do not estimate the sum of the individual weights squared.

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.

Passenger-miles traveled (PMT) are accumulated using a process similar to travel time. First, we convert individual trip PMT into an average PMT for trips from o to d starting in interval τ.

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

(Equation 15)

For trips that cannot be completed before the end of the simulation, see the following section for the estimation of total trip distance.

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

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

(Equation 16)

Equation 17 defines the aggregate PMT across all o, d, τ:

$$X = \sum_{\forall o,d,\tau} X_{o,d,\tau} n_{o,d,\tau}$$

(Equation 17)

Passenger-miles delivered (PMD) and passenger-trips delivered (PTD) are measures that introduce notions of travel quality into throughput. Simple PMT measures often 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 five-mile trip completed in 15 minutes counts equally with the same five-mile trip completed in two hours. Here, we restrict the accounting of passenger-miles traveled (or passenger-trips delivered) to trips that successfully complete their trips prior to the end of the simulation (or some other logical time-point). Let $\dot{\mathbf{I}}^k_{o,d,\tau}$ be the set of trips from o to d starting in interval τ that complete their trip before the simulation ends (or some other logical time-cutoff).

Equation 18 shows passenger-trips delivered (PTD) calculated at the o, d, τ level.

$$Y_{o,d,\tau}^{k} = \frac{\sum_{i \in \mathbf{I}_{o,d,\tau}^{k}} x_i^k}{n_{o,d,\tau}^{k}}$$
(Equation 18)

Equation 19 finds the average PTD for all trips from o to d starting in interval τ over all operational conditions $k \in K$:

$$Y_{o,d,\tau} = \sum_{k \in K} Y_{o,d,\tau}^{k} p_k$$
(Equation 19)

Equation 20 defines the aggregate PTD across all o, d, τ:

$$Y = \sum_{\forall o,d,\tau} Y_{o,d,\tau}\, n_{o,d,\tau}$$
(Equation 20)

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

$$Z_{o,d,\tau}^{k} = \frac{\sum_{i \in \mathbf{I}_{o,d,\tau}^{k}} s_i^k x_i^k}{n_{o,d,\tau}^{k}}$$
(Equation 21)

Equation 22 finds the average PMD for all trips from o to d starting in interval τ over all operational conditions $k \in K$:

$$Z_{o,d,\tau} = \sum_{k \in K} Z_{o,d,\tau}^{k} p_k$$
(Equation 22)

Equation 23 defines the aggregate PMD across all o, d, τ:

$$Z = \sum_{\forall o,d,\tau} Z_{o,d,\tau}\, n_{o,d,\tau}$$
(Equation 23)

For example, in the Dallas ICM Corridor, the simulation period is from 5:30 a.m. to 11:00 a.m., while the peak hours are from 6:30 a.m. to 9:00 a.m. It is anticipated that with or without an ICM strategy in place, all trips that begin in the peak-period should be completed before the simulation ends at 11:00 a.m. In this case, there may be little difference in PMT or PMD when 11:00 a.m. is used as the logical time cutoff. In order to measure the peak capability of the system to deliver trips, the set of trips counting towards PMD could potentially be restricted to those trips that can both begin and complete their trips in the peak-period (6:30 a.m. to 9:00 a.m.). At this point, it is premature to define a specific time cutoff for PMD to be applied in all three sites.

Restricting the calculation of measures to selected cohorts also is relevant to the calculation of delay and travel time reliability measures. Although peak-periods vary among the AMS sites in terms of the onset and duration of congestion, a consistent set of trips that contribute to measuring calculation (others simply run interference) should be identified. As in the case of the throughput time cutoff point, U.S. DOT may wish to prescribe specific times in the future.

At this time, it is unclear whether PMT, PMD, or PTD will be the selected performance measure for corridor throughput, pending clarification that all ICM models can support these measures.

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 $n^0_{o,d,\tau}$ trips from o to d starting in 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:

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

(Equation 24)

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 $\overleftarrow{x}_i^k$ be the distance traveled on the trip i up to the point where the simulation ends, and let $\overleftarrow{t}_i^k$ 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 25:

$$\overleftarrow{v}_i^k = \frac{\overleftarrow{x}_i^k}{\overleftarrow{t}_i^k}$$

(Equation 25)

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:

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

(Equation 26)

$$x_i^k = \max\left\{\ddot{X}_{o,d,\tau}^{0},\ \bar{x}_i^k\right\}$$ (Equation 27)

Comparing Pre- 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 (here referred to as a case, but often called an alternative). The complete suite of delay, travel time reliability, and throughput measures is calculated independently for each case (e.g., pre-ICM). Comparisons of the resulting measures are then made to characterize corridor performance under each case.

Comparing Observed and Simulated Performance Measures

These few key measures have been defined in detail for national consistency across all AMS sites. Sites also have 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 quite 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.

APPENDIX D. Method to Determine Transit Shift in Simulation – San Diego I-15

This appendix describes the methodology used in determining whether a vehicle shifts to riding BRT (transit) in simulation for the ICM AMS effort underway for the San Diego I-15 site. The BRT service is proposed to have five stations within the study corridor, each having direct connections to the HOT lane and also access to the General Purpose Lanes.

Key Variables

The following variables are critical to the function of the algorithm. The appropriate values assigned to all variables must be approved by SANDAG prior to implementing the algorithm.

- **BRT Cost (BRTCost).** This value represents the BRT fare in terms of dollars per ride. **Recommended value: $5 per ride**.
- **Auto Operating Cost (AutoOpCost).** This value represents the cost of driving. **Recommended value: $0.35/mile*Length(miles)**.
- **BRT Off-Vehicle Travel Time (BRTOVTT).** This value represents a traveler's time spent outside a BRT if the traveler decides to shift from driving to BRT riding. It includes the time that the traveler accessing the BRT station, waiting for a BRT, and exiting the BRT station at the destination station. **Recommended value: 18 minutes**. (6 minutes to access the BRT station, 6 minutes of waiting for BRT, and 6 minutes to exit the final BRT station).
- **Auto Off-Vehicle Travel time (AutoOVTT).** This value represents a traveler's time spent outside his/her vehicle if the traveler decides to continue driving. **Recommended value: 0 minute**.
- **BRT In-Vehicle Travel Time (BRTIVTT).** This value represents a traveler's time spent inside a BRT. It is assumed that BRT will travel at an average speed of 60 mph. **Recommended value: BRT Route Distance (miles) per 60 mph**.
- **Auto In-Vehicle Travel Time (AutoIVTT).** This value represents a traveler's time spent inside the vehicle he/she is driving. The travel time will be directly extracted from the simulation model.
- **Driver Income (Income).** This value represents the income of the driver, expressed in terms of dollars per hour. This value will be considered one of the factors influencing the driver's decision on either continuing driving or taking BRT. **Recommended value: $12 per hour – $100 per hour, with 50 percent of drivers at or below $24 per hour.**

Algorithm Calculations

The algorithm calculates whether a driver shifts to BRT in the following manner:

The general purpose and managed lanes (ML) are divided into segments at each BRT station. A "segment" is defined as a length of roadway lying between successive access points to BRT stations.

- The cost of driving is calculated at the decision point upstream of each BRT access point based on the following utility function.

$$U_{Auto} = e^{4.110 - 0.025*AutoIVTT - 0.050*AutoOVTT - 0.025*AutoOpCost + 0.000*Income}$$

The cost of riding BRT is calculated at the decision point upstream of each BRT access point based on the following utility function.

$$U_{BRT} = e^{-0.855 - 0.025*BRTIVTT - 0.050*BRTOVTT - 0.025*BRTCost - 0.050*Income}$$

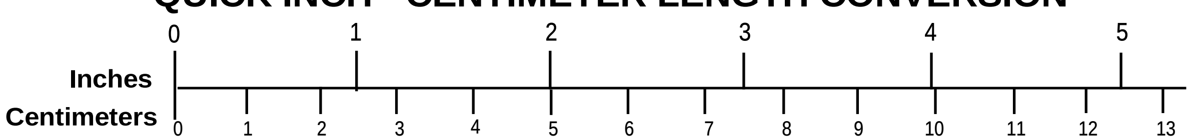
The probability that a traveler would shift to using BRT is determined as shown below.

$$PROB_{BRT} = \frac{U_{BRT}}{U_{Auto} + U_{BRT}}$$

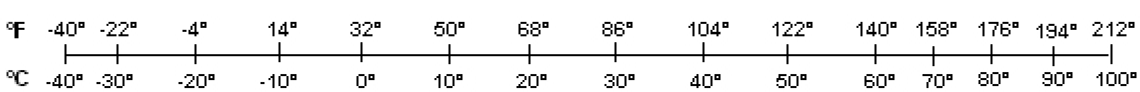
APPENDIX E. Metric/English Conversion Factors

ENGLISH TO METRIC	METRIC TO ENGLISH)
LENGTH (APPROXIMATE)	**LENGTH (APPROXIMATE)**
1 inch (in) = 2.5 centimeters (cm)	1 millimeter (mm) = 0.04 inch (in)
1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
	1 kilometer (km) = 0.6 mile (mi)
AREA (APPROXIMATE)	**AREA (APPROXIMATE)**
1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)	1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)	1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)	
MASS - WEIGHT (APPROXIMATE)	**MASS - WEIGHT (APPROXIMATE)**
1 ounce (oz) = 28 grams (gm)	1 gram (gm) = 0.036 ounce (oz)
1 pound (lb) = 0.45 kilogram (kg)	1 kilogram (kg) = 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)	1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons
VOLUME (APPROXIMATE)	**VOLUME (APPROXIMATE)**
1 teaspoon (tsp) = 5 milliliters (ml)	1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 tablespoon (tbsp) = 15 milliliters (ml)	1 liter (l) = 2.1 pints (pt)
1 fluid ounce (fl oz) = 30 milliliters (ml)	1 liter (l) = 1.06 quarts (qt)
1 cup (c) = 0.24 liter (l)	1 liter (l) = 0.26 gallon (gal)
1 pint (pt) = 0.47 liter (l)	
1 quart (qt) = 0.96 liter (l)	
1 gallon (gal) = 3.8 liters (l)	
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)	1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)	1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)
TEMPERATURE (EXACT)	**TEMPERATURE (EXACT)**
[(x-32)(5/9)] °F = y °C	[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

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

FHWA-JPO-10-039
EDL No. 14946

U.S. Department of Transportation
Research and Innovative Technology Administration