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Final Report for Task Order 6613

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Final Report for PATH Task Order 6613

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ABSTRACT

This report describes the Stage One work of the US Department of Transportation's (DOT) federally-sponsored Integrated Corridor Management (ICM) Program for the I-15 Corridor in San Diego County, California, between State Route 52 in the city of San Diego and State Route 78 in the city of Escondido. The development work is based on the systems engineering process whereby this work focused specifically on the concept of operations and the system requirements specifications. The development of the concept of operations consists of the following elements: vision, goals and objectives for the I-15 corridor; operational concept description, approaches, and strategies; corridor user needs; implementation issues; institutional framework; and operational scenarios. The development of the system requirements specification primarily depends on the set of user needs developed in concept of operations. Seventeen user needs were transformed into 17 corresponding functional areas for the I-15 ICMS system, which formed the core of the development of the system requirements. The report also includes a description of the data available for the next Phase of I-15 ICM effort (analysis, modeling and simulation).

Key Words: *integrated corridor management, concept of operations, system requirements specifications*

EXECUTIVE SUMMARY

This report constitutes the final deliverable for PATH Project Task Order 6613 under contract 65A0208 — "San Diego Integrated Corridor Management Demonstration I-15 in San Diego County". We describe in this report the Stage One work of the US Department of Transportation's (DOT) federally-sponsored Integrated Corridor Management System Program for the I-15 Corridor in San Diego County, California between State Route 52 in the city of San Diego and State Route 78 in the city of Escondido.

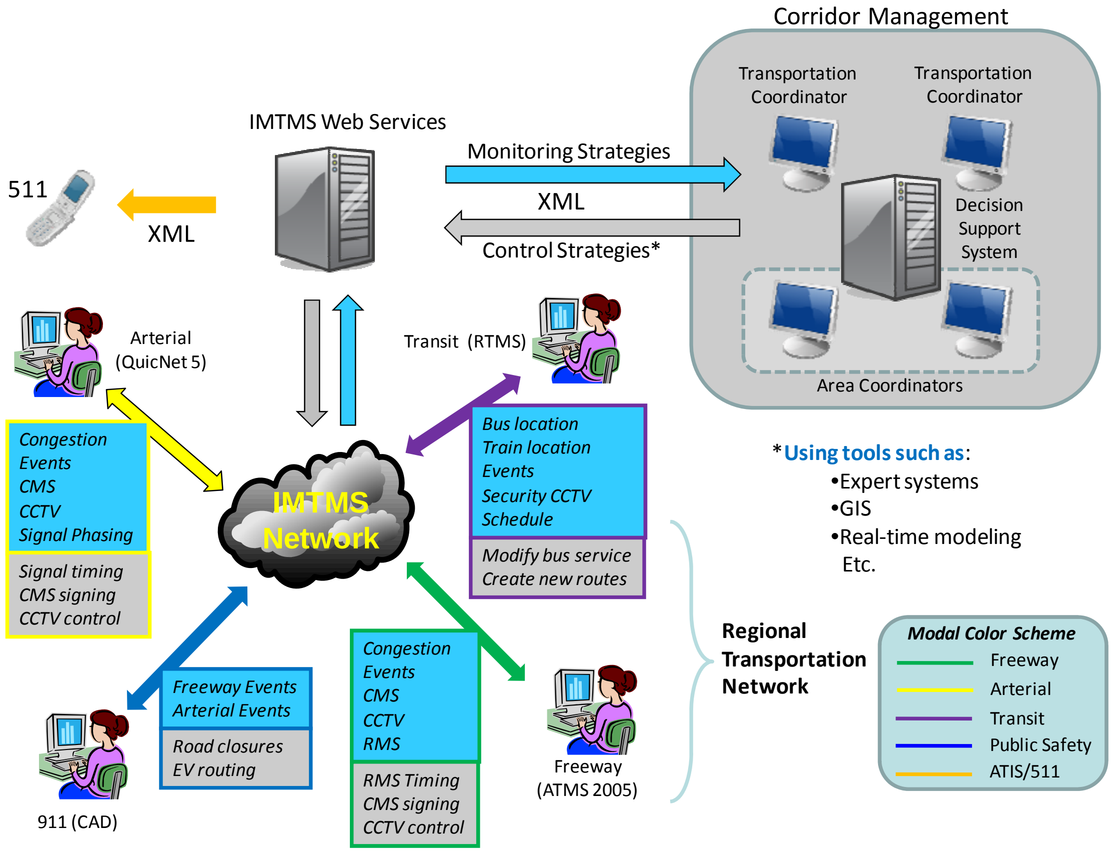
The development work is based on the systems engineering process whereby the focus was specifically on two primary development research efforts: Concept of Operations and System Requirements Specifications. The development of the Concept of Operations followed a specific investigative process and consisted of the following elements in sequential order for the I-15 ICM system: vision, goals and objectives for the I-15 corridor; operational concept description, approaches, and strategies; corridor user needs; implementation issues; institutional framework; and operational scenarios. The development of the System Requirements Specifications depended primarily on the set of user needs that we developed as part of the Concept of Operations.

For the Concept of Operations, the ICM system concept for the I-15 Corridor consisted of the following four primary elements:

- Share/Distribute Information
  - Pre-trip traveler information
  - En-route traveler information
- Improve Roadway Junctions/Interfaces
  - Transit signal priority
  - Freeway ramp meters/arterial traffic signal coordination
  - Bus rapid transit
- Accommodate/Promote Network Shifts
  - Modify ramp metering rates
  - Congestion pricing for managed lanes
- Manage (Short-Term) Capacity/Demand
  - Modify HOV restrictions

In terms of hardware and software components, a lot of what San Diego envisions for its I-15 ICM system already exists in that there are various systems that manage the networks for individual modes – called modal management systems – for example, for the freeway, arterial, and transit networks. Connecting these individual systems is the Intermodal Transportation Management System (IMTMS) – the "glue" that ties together the modal management systems and allows for the sharing of data and functional capabilities across modes. For example, IMTMS is what allows a transit agency to receive information on traffic conditions, and IMTMS is the system that allows cities to share event management information, as well as traffic video and camera control, with other cities and Caltrans. IMTMS facilitates communication between agencies within an individual management system and between different management systems.

There is, however, a major part of the I-15 ICM system that is currently at the conceptual level. It is called the Decision Support System (DSS). DSS will support the ability to generate suggested action plans in response to regional events. The events may be recurring (morning and afternoon peak travel), planned (San Diego Chargers football games at Qualcomm Stadium), or unplanned and unexpected (brush fires such as what occurred in October 2007). The figure below shows schematically the IMTMS and its connections to the various modal management systems together with its connection to the DSS, depicted in the upper right corner (highlighted in a grayish-blue square). While IMTMS collects and routes data (shown as the blue portion of the modal boxes), DSS will consist of the tools needed to develop, recommend and transmit actions to specific traffic contro1 devices and public transportation systems (shown as the gray portion of the modal boxes).



The I-15 ICM system will need to operate in many different environments and respond to a variety of transportation-related situations along the corridor. The following six scenarios are representative of travel conditions along the I-15 Corridor in which the ICM system will need to operate:

- Daily operations of recurring congestion
- Freeway incident, major or minor
- Arterial incident, major or minor
- Transit incident
- Special planned event
- Disaster response

ICMS system users include transportation planners, operations supervisors, traffic engineers, public safety dispatchers, transit dispatchers and transportation management center operators. The Concept of Operations captured a user-oriented perspective that addresses core issues about what the corridor currently lacks and what the ICM system could provide; currently known elements and high-level system capabilities; geographical and physical extents of the I-15 Corridor; stakeholders involved and their responsibilities; time sequence of activities to be performed; and resources needed to design, build, operate, and maintain the ICM system for the I-15 Corridor.

The primary output from this user-perspective approach was the set of User Needs, which are provided in the following list:

1. Store configuration data
2. Collect and process data
3. Access and store historical data
4. Publish information to *system managers*
5. Interactively conference with multiple agencies
6. Display information
7. Coordinate transportation and public safety operations for event management
8. Share control of field devices
9. Manage video imagery
10. Respond to corridor events (planned or unplanned)
11. Assess impact of corridor management strategies
12. Publish information to *system users*
13. Measure *corridor performance*
14. Manage corridor demand and capacity to optimize long-term performance
15. Measure *system performance*
16. Manage the ICM system including time synchronization, user accounts, data backup and archival
17. Provide documentation and training

These 17 user needs were transformed into 17 corresponding functional areas for the I-15 ICMS system, which formed the core of the development of the System Requirements Specifications. Each user need was partitioned to an appropriate level of detail to develop a corresponding set of unambiguous, complete and correct system requirements

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CHAPTER 1

INTRODUCTION

This report constitutes the final deliverable for PATH Project Task Order 6613 under contract 65A0208 — "San Diego Integrated Corridor Management Demonstration I-15 in San Diego County". We describe in this report the Stage One work of the US Department of Transportation's (DOT) federally-sponsored Integrated Corridor Management System Program for the I-15 Corridor in San Diego County, California.

The participation of San Diego area transportation and public safety stakeholders, led by the San Diego Association of Governments and representing the city and county of San Diego, the cities of Escondido and Poway, and the two primary transit agencies – Metropolitan Transit System and North County Transit District, played a valuable role throughout the project in providing input and feedback to the PATH research team as it developed its primary deliverables: Concept of Operations (ConOps) and System Requirements Specification (SysReqSpec).

The San Diego site is the I-15 Corridor between State Route 52 in the city of San Diego and State Route 78 in the city of Escondido. I-15 is a principal route through this economically vital and fast-growing region in California. Already a model for the multi-modal deployment of the latest as well as emerging Intelligent Transportation Systems (ITS) technologies for data collection, demand management and congestion pricing strategies, the region is dedicated to providing the added value from systemic, comprehensive, and integrated approaches to transportation management for this corridor. San Diego's vision for the I-15 Corridor under such approaches includes working collaboratively and cooperatively through ongoing institutional partnerships; giving travelers the opportunity to make seamless and convenient shifts among travel modes and among the corridor's networks to complete their trips; and improving person- and vehicle-throughput, connectivity, safety, environmental compatibility, and enhancing accessibility to reach destination points in a reliable and timely manner.

Stage One of the ICM Program focused on the initial phases of the systems engineering process for a project as shown schematically in the "V" diagram in Figure 1, that is, development of the ConOps and the SysReqSpec as depicted on the left hand side of Figure 1. The ConOps and SysReqSpec are two of the three components for San Diego's Technical Application for Stage Two of the ICM Program, which consists of the analysis, modeling, and simulation of the corridor using accumulated sample data that was provided to US DOT by the San Diego stakeholder team.

Development of the ConOps and the SysReqSpec underwent a draft-review-revision process and the final version of each of these two deliverables were submitted to US DOT together with a Technical Application Summary for final review as the US DOT goes through its downselect process to determine which of the eight Stage One Pioneer Sites would be invited to continue to participate in Stage Two of the ICM Program. While summaries of the final versions of the ConOps and the SysReqSpec are provided in Appendices A and B of this report, the complete version of each product may be obtained by contacting Alex Estrella at SANDAG at aes@sandag.org.

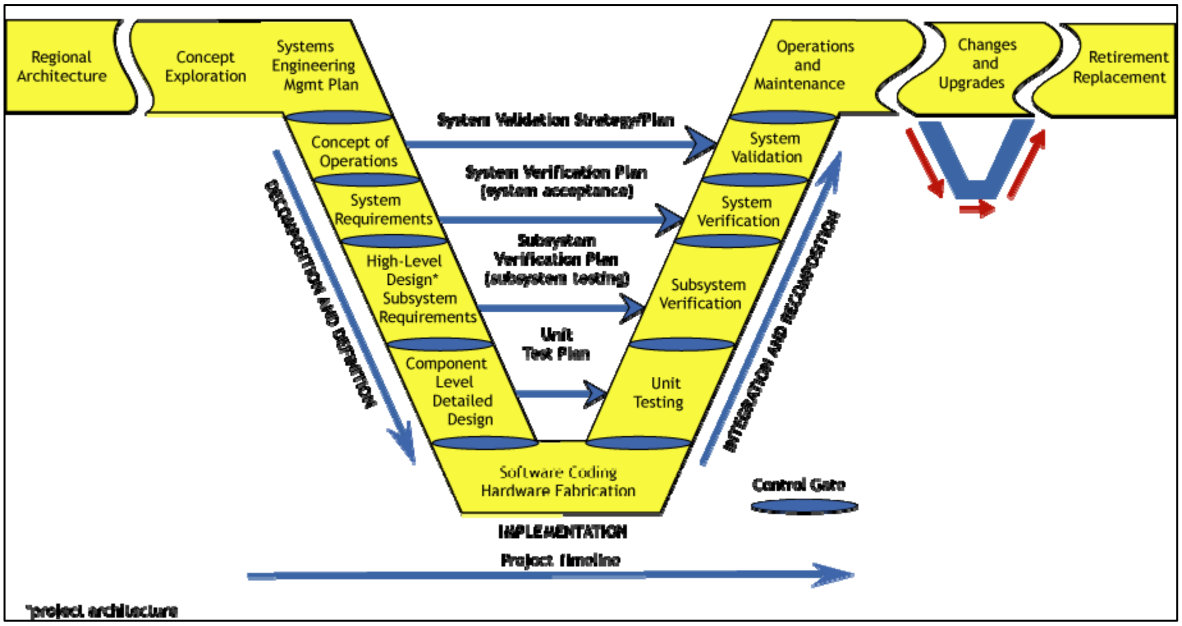

Figure 1: The "V" Diagram for the Systems Engineering Process

CHAPTER 2

CONCEPT OF OPERATIONS AND SYSTEM REQUIREMENTS SPECIFICATION PRODUCTS

The San Diego ConOps and SysReqSpec documents, which represent the I-15 ICMS system concept and how it will operate, were produced in a consistent and logical fashion. Content consistency is evident in numerous ways, yet primarily through the one-to-one relationship between the set of 17 User Needs (ConOps Sections 1.8 and 4.3; SysReqSpec 3.4) and the set of 17 system functional areas that define at a high-level the types of system requirements the I-15 ICMS system must satisfy (SysReqSpec Sections 3.7 and 3.8). The set of 17 functional areas for the I-15 ICMS system requirements was derived from the corresponding set of User Needs (Table 1). Each of the 17 major functions contains all its associated requirement types, including constraints, data, functional, interface, hardware, and performance. This approach is expected to streamline the transition to the design phase of the ICMS system by grouping all requirements related to a single function. A description of each of these 17 functional areas is in Appendix B. Moreover by design we have listed the User Needs and system functional areas in a specific order to be consistent with the normal flow of activities in corridor operations.

Another area of content consistency between the ConOps and the SysReqSpec documents connects the state of the corridor with the operational mode and state of the ICMS system. We described the corridor state in terms of six operational scenarios (ConOps, Section 5), which are representative of travel conditions within the I-15 corridor in which the ICMS system will need to operate:

- Daily Operations with morning and afternoon peak travel;
- Major/minor freeway incident;
- Major/minor arterial incident;
- Transit incident;
- Special (Planned Event; and
- Disaster/Emergency Response.

In the SysReqSpec document (Sections 2.3 and 2.31), we presented ICMS system operational modes and states. The ICMS system will operate in two basic modes (normal, failure). During ICMS system operation, transitions to and from various operational states will occur in the Normal Mode. These transitions will closely track changes in the state of the corridor itself, i.e., if an incident occurs in the corridor, the ICMS system transitions to an event management and response plan state.

Additional areas of content consistency between the ConOps and the SySReqSpec are shown in Table 2 together with references to the relevant sections of each document.

The development of the set of proposed requirements – in terms of both quality and quantity – has resulted in a product that is well suited for the San Diego region's unique combination of operating characteristics, transportation assets, and mobility management strategies. The SysReqSpec document provides a complete picture of San Diego's ICMS system, including its description, context, subsystems, users and their roles both individually and as a management team, constraints, operational modes and states. The San Diego local area Stakeholder Working Group provided the technical and operational foundation for the SysReqSpec document. We conducted a series of workshops with both a "core" Working Group and an expanded team that included regional public safety personnel. This iterative process resulted in a set of detailed requirements reflecting the specific needs and systems of the San Diego Region. The Federal Technical Assistance Team's two site visits provided additional guidance on the development of both User Needs and System Requirements resulting in the creation of a high-level functional decomposition based on our set of 17 User Needs, which provided the significant benefit of maintaining a one-to-one correspondence between the requirements within each functional area and its corresponding User Need.

Our approach has given the local stakeholder team an opportunity to take full advantage of the nature of the San Diego region's current and successful transportation management strategies. Moreover, the team has developed system requirements for the ICMS system in a systematic fashion that is detailed and complete. We are confident that this will also allow the San Diego region to move toward the system design phase in an efficient manner. This methodology provides SANDAG with the added benefit that the I-15 ICMS system should be readily transportable to other corridors within the San Diego region without major modifications and SANDAG fully intends to expand the ICM corridors beyond I-15. Guided by this strategy, we followed a detailed and iterative process that resulted in an extensive set of requirements in both depth and breadth; moreover, our written requirements were found to be accurate, complete, and clearly written by the US DOT Team.

Table 1: ICMS Concept of Operations User Needs

Number and Title	Description/Rationale
1. Access/Store ICMS Configuration Data	Create and manage a configuration database that maintains static information on various I-15 corridor parameters.
2. Collect and Process Data	Collect data from a variety of existing and planned systems after which processing algorithms are invoked to produce a higher level of information aggregation.
3. Access/Store ICMS Historical Information	Create and populate a historical database that contains real- time information on corridor performance derived from data collected.
4. Publish Information to System Managers	Disseminate data from all sources to agencies that manage one or more modes in the integrated corridor network.
5. Interactively Conference with Multiple Agencies	Allow system managers from multiple agencies to directly collaborate in real-time prior to, during or after a major corridor event using voice, video and data formats.
6. Display Information	Display a variety of data formats that agency decision-makers can use to visualize corridor operations, make decisions and take actions to implement the various decision components.
7. Coordinate Transportation & Public Safety Operations	Promote coordination and sharing of data between transportation and public safety communities.
8. Share Control of Devices	Allow agencies to remotely control selected field device functions regardless of location or agency ownership based on interagency agreements.
9. Manage Video Imagery	Produce and share among system users a variety of video imagery that shows a critical view of emerging and on-going corridor events.
10. Respond to Corridor Planned and Unplanned Events	Allows ICMS users and managers to use a decision-support tool that fuses data collected at the event site to generate a response plan that can be updated as necessary before transmitting plan components to the affected systems.
11. Assess Impact of Corridor Management Strategies	Allows corridor managers to model various traffic and service management strategies to gauge their impact on corridor performance and return timely results to affect decision-making during a major event.
12. Publish Information to System Users	Provides corridor information to the regional 511 system for dissemination to various system users across a variety of media; makes available a standard XML data stream and video imagery to other entities for dissemination to system users.
13. Measure Corridor Performance	Examines multi-modal corridor data from both short-term and long-term perspectives from both historical databases and PeMS.
14. Manage Corridor Demand and Capacity to Optimize Long-Term Performance	Provides for corridor managers to collaboratively develop longer-term corridor capacity and demand management strategies.

Number and Title	Description/Rationale
15. Measure System Performance	Monitoring of field devices, server systems and communications networks needed to support corridor management functions. Based on monitored data, metrics for system components will be measured and stored in the historical database.
16. Manage ICMS System	Provides administrative functions of ICMS including data management for ICMS configuration data, user account management incorporating system-wide security functions and IT- centric functions such as data backup and archival.
17. Maintain the ICMS System Throughout its Full Life-Cycle	Provides logistical support to the ICMS system through its full life-cycle (definition, development, testing, documentation, training and maintenance).

Table 2: Consistency of Content between ConOps and SysReqSpec Documents

Area of Content Consistency	Document References
Goals and objectives of proposed I-15 ICMS system	ConOps, Sections 1.6 and 4.1; SysReqSpec, Section 1.2.2
Timeline for operational deployment of corridor assets	ConOps, Section 4.5 (Figure 4-1); SysReqSpec, Section 2.7.6 (Table 2-5)
Decision Support System	ConOps, Section 5 (Figure 5-2); SysReqSpec, Section 2.2.3 (Figure 2-7)
Performance Measures	ConOps, Sections 4.9, 4.9.1, and 4.9.2; SysReqSpec, Section 3.8.13
Intermodal Transportation Management System (IMTMS)	ConOps, Sections 3.4, 5 (Figure 5-1); SysReqSpec Section 2.2.2 (Figure 2-3)
Modal management systems (ATMS 2005, MLCS, RAMS, and RTMS)	ConOps, Section 3.4; SysReqSpec, Sections 2.2.2.1, 2.2.2.2, 2.2.2.6, and 2.2.2.7

CHAPTER 3

QUALITY AND AVAILABILITY OF THE I-15 CORRIDOR DATA

The I-15 stakeholder team provided Sample Data to US DOT for review (Appendix C). This sample data indicated that there are four networks that have real-time or near real-time data collection capability as follows:

1. I-15 freeway general purpose/mainline lanes
2. I-15 freeway Managed Lanes (ML)
3. Arterial network for three primary I-15 corridor arterials
   - Centre City Parkway
   - Pomerado Road
   - Kearny Villa/Black Mountain Road
4. Transit network

The I-15 Managed Lanes facility is currently within the median of I-15 between SR 163 and SR 56 — corresponding to the eight-mile South Segment of the full 21-mile ML facility — and is a two-lane reversible, high occupancy toll (HOT) facility. This barrier-separated facility operates southbound during the a.m. peak period, northbound during the p.m. peak period, and all day (northbound) during the weekend. The Middle Segment of the ML facility, which is currently under construction, will be the first of the three ML segments to become operational; it is being deployed in phases between July 2008 and January 2009. Data for the I-15 general purpose lanes, current Reversible Lanes facility (and future ML facility) and on-ramps consist of real-time vehicle occupancy and count data collected every 30 seconds from embedded inductive loops and non-intrusive radar detectors. Data quality and coverage along the I-15 freeway generally lies between 88-90%, which is above and beyond the statewide average and provides evidence that Caltrans' District 11 (San Diego County) has the best quality and coverage per freeway lane mile in the state.

The Arterial Network encompasses the cities of San Diego, Poway, and Escondido with the following three primary arterials identified as candidates to carry excess capacity in their respective jurisdictions: Kearny Villa Road/Black Mountain Road (7 miles), Pomerado Road (13 miles); and Centre City Parkway (6 miles). Additionally, there are secondary parallel routes that can be used in the case of emergencies. Vehicle counts (AADT) and turning movements have, until recently, been the primary source of arterial data; however, arterial data are currently in the process of being significantly expanded using detection technologies including inductive loops and wireless sensors to collect occupancy data that is at a much finer level than simply AADT. Data is being collected on the three primary I-15 corridor arterials at least once at each mid-block location as part of the initial deployment of Arterial-Performance Measurement System (A-PeMS), the web-based performance measurement and evaluation tool that will expand the coverage of the statewide PeMS system from freeways alone to freeways and arterials. While the initial deployment of A-PeMS will occur in July 2008, there will be extended implementation of A-PeMS to additional I-15 arterials by July 2009. The current A-PeMS application is expected to have between 85% and 90% accuracy rate.

The Transit Network consists of express bus service into San Diego operated by MTS (Routes 20, 810, 820, 850, and 860) and local service operated by NCTD (Route 350). Bus Rapid Transit system service will be operational with the Managed Lanes system and will include service from three stations along the corridor. In addition to freeway and arterial PeMS, a Transit-PeMS (T-PeMS) is also currently under development with its functional framework complete by July 2008 and initial deployment scheduled for July 2009.

The ConOps and SysReqSpec identify the performance measures and data collection tools that will be used to analyze, model, and simulate the I-15 ICMS system ─ freeway (general purpose and managed lanes), arterial, and transit networks ─ as part of the Stage Two AMS (Con Ops Section 4.9 – 4.9.2; SysReqSpec 3.8.13). SANDAG has a GIS based comprehensive four-step model that can provide trip tables as inputs to more detailed tools such as simulation models. Also the region has a complete inventory of all network data in electronic format; moreover, the Caltrans District 11 Transportation Management Center and the traffic signal QuicNet 4 software can provide all the control data (ramp metering rates, signal timing plans etc.). Key available performance data that will be provided through PeMS and A-PeMS include, but are not limited to, estimation of vehicle and person miles traveled, vehicle and person hours traveled, travel times, travel speeds, level of service, and vehicle and person hours of delay. Key available transit performance measures that will be provided through T-PeMS include real-time transit arrivals, schedules, ridership levels, percent transit vehicle capacity utilization, and other vehicle transit fare or security monitoring indicators. In sum, all possible data requirements are readily available.

CHAPTER 4

POTENTIAL BENEFITS OF PROPOSED I-15 ICMS

The I-15 Corridor is currently undergoing significant design and operational improvements including

- Construction of the 21-mile long *managed lanes* (*ML) facility* that will greatly expand the current eight-mile long reversible express lanes facility at the southern end of the corridor. The ML facility is divided into three segments as noted in Figure 2.
- A high-frequency *Bus Rapid Transit (BRT)* express bus system.
- The *511 traveler information system* – launched in February 2007 – while available for all San Diego area travelers, allows travelers using the I-15 corridor to make better-informed decisions about their travel along the corridor, such as whether to take their trip, when to begin their trip, what travel mode to take, such as transit, or what route to take
- Collection of arterial data as part of the initial deployment of *Arterial-PeMS* in July 2008 on I-15's three primary arterials parallel to I-15, namely, Centre City Parkway (6 miles), Pomerado Road (13 miles), and Kearny Villa/Black Mountain Road (7 miles).

In terms of operational approaches, the I-15 ICMS system will consist of the sharing and dissemination of information among the corridor's agencies; improving network junctions especially at freeway on-ramps and off-ramps where the freeway and arterial networks converge; promoting shifts between networks, such as arterials accommodating traffic diverted from I-15 or travelers using transit instead of their cars based on information from the 511 system; and managing the travel desires of travelers given the capacity limits of available roadway facilities in both the short- and long-term (ConOps Section 4.2).

In terms of hardware and software components, some of what San Diego envisions for its I-15 ICMS system already exists (ConOps Section 4.5; SysReqSpec Section 2.7.6) in that there are various systems that manage the networks for individual modes – modal management systems – for example, for the freeway, arterial, and transit networks. Connecting these individual systems is the Intermodal Transportation Management System (IMTMS) – the "glue" that ties together the modal management systems and allows for the sharing of data and functional capabilities across modes. IMTMS facilitates communication between agencies within an individual management system and between different management systems. Table 3 shows a timeline for the operational deployment of the I-15 corridor assets.

There is, however, a major part of the I-15 ICM system that is currently at the conceptual level. It is called the Decision Support System (DSS) (ConOps Sections 4.5 and 5; SysReqSpec Sections 2.2.3 and 2.2.4). DSS will support the ability to generate suggested action plans in response to regional events. The events may be recurring (morning and afternoon peak travel), planned (San Diego Chargers football games at Qualcomm Stadium), or unplanned and unexpected (e.g., brush fires that struck San Diego County in October 2007). DSS combines existing model management data sources with data fusion tools to aid in the complex decision-making inherent in corridor operations. Such tools are needed to develop, recommend and transmit actions to specific traffic control devices and public transportation systems (shown as the gray portion of the modal boxes). The significance of the DSS lies in the fact that modal actions in response to short-term or long-term impacts on the corridor will be coordinated and not carried out in isolation as is usually the case.

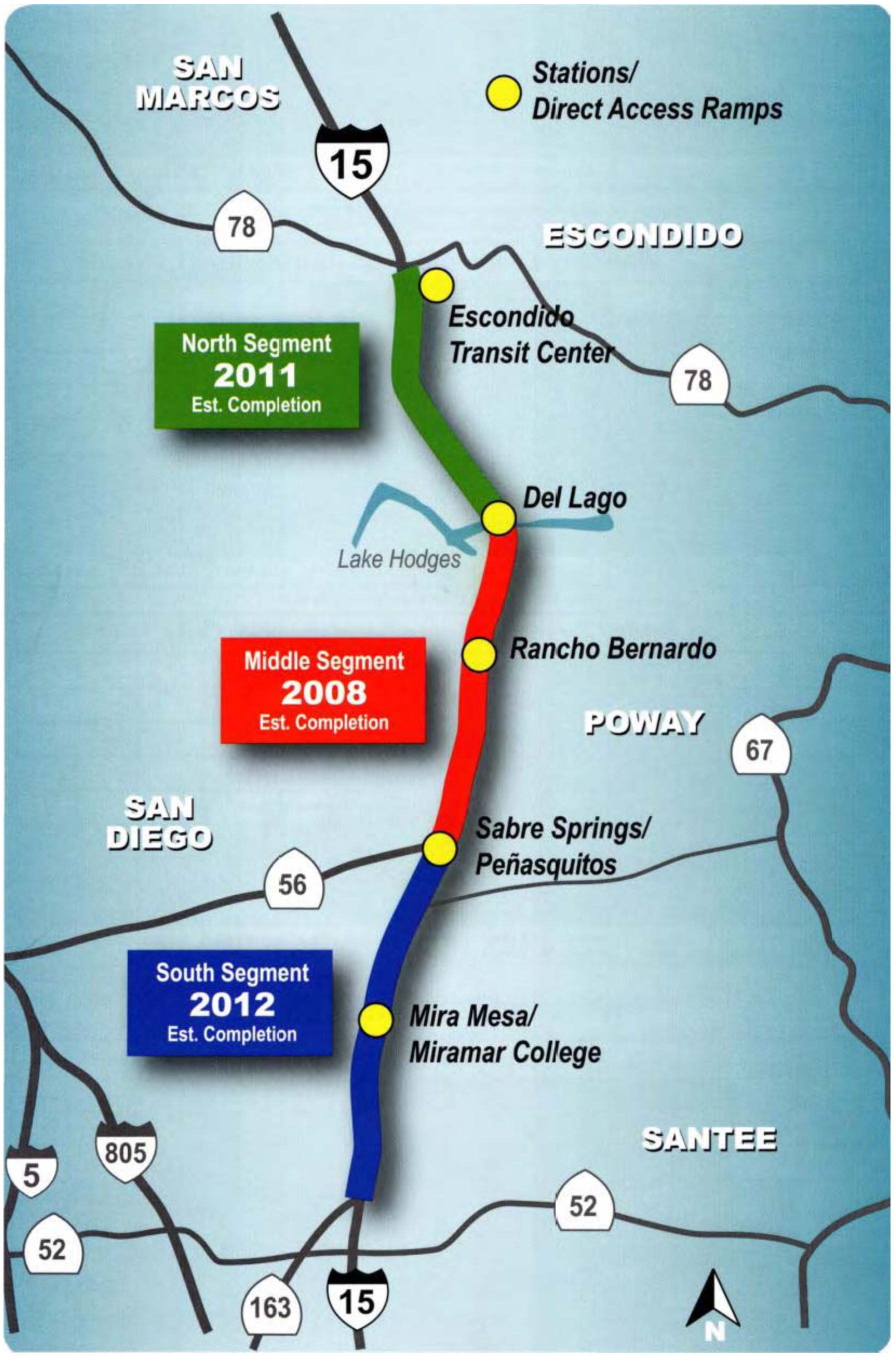

Figure 2: I-15 Managed Lanes Segments

Table 3. Schedule for Operational Deployment of Assets—I-15 Corridor

I-15 Corridor Assets	Deployment Schedule
1. Managed Lanes Control System (MLCS) (together with Congestion Pricing System)	
a. Middle Segment	**a. Phased deployment: Jul 2008–Jan 2009**
b. North Segment	**b. January 2012**
c. South Segment	**c. January 2013**
2. Bus Rapid Transit Stations & Direct Access Ramps	
a. Middle Segment	a. **Phased deployment: Jul 2008-Jan 2009**
b. North Segment	b. **January 2012**
c. South Segment	c. **January 2013**
d. New vehicles, more frequent service, Bus arrival signage	d. **January 2013**
3. Arterial Data Collection Capabilities	
a. A-PeMS Initial Deployment Phase along primary I-15 arterials (Centre City Parkway, Pomerado Road, Kearny Villa/Black Mountain Road)	**a. July 2008**
b. Extended Implementation beyond I-15 arterials	**b. July 2009**
4. Advanced Transportation Management System (ATMS)	**Operational**
5. Intermodal Transportation Management System (IMTMS) (less RIWS and RAMS)	**Operational**
6. Lane Closure System (LCS)	**Operational**
7. Regional Arterial Management System (RAMS)	
a. **Initial Deployment Phase**	a. **July 2008**
b. **Integration of QuicNet 4+ into IMTMS environment**	b. **January 2009**
c. **Full Implementation Phase (regionalization of QuicNet 4+)**	c. **March 2009**
8. Regional Event Management System (REMS) (currently CHP CAD)	**Operational**
9. Regional Integrated Work Stations (RIWS)	
a. **Acceptance testing**	**a. Completed**

I-15 Corridor Assets	Deployment Schedule
b. **Phased implementation subject to regional agreements**	**b. 2009**
10. Regional Transit Management System (RTMS)	**Operational**
11. CHP Media Incident feed and Integration into IMTMS	**Operational**
12. Regional Communication Networks	
a. Communication Plan with gaps identified and most cost effective strategies identified; 90% complete by 2012	**a. April 2008**
b. South Segment of Managed Lanes	**b. 2008**
c. Middle Segment of Managed Lanes	**c. 2012**
d. North Segment of Managed Lanes	**d. 2012**
13. Caltrans Fiber Optic Network	**Oct– Dec 2008 (Phase 1)/2012 (Phase 2)**
14. Upgrades in Freeway Management System monitoring capabilities (more detectors and full coverage CCTV).	**Oct – Dec 2008 (Phase 1)/2012 (Phase 2)**
15. Revised/Upgraded Incident Management procedures for Automated Detection and Response	**Oct – Dec 2008 (Phase 1)/2012 (Phase**
16. Expanded implementation of Changeable Message Signs (along I-15 Managed Lanes)	**Oct – Dec 2008 (Phase 1)/2012 (Phase 2)**
17. Upgrading of I-15 Reversible Lane Control System (RLCS) on South Segment of I-15	**Completed**
18. Compass Card Financial Clearinghouse System	
a. **Pre-Test Phase**	**a. Completed (April–June 2007)**
b. **Employee Initial Test Phase (SANDAG, MTS, and NCTD)**	**b. October 2007 – July 2008**
c. **Mini-Customer Initial Test**	**c. March 2008**
d. **Full System Launch**	**d. July 2008**
19. 511 Advanced Traveler Information System	
a. **Initial System Launch for phone and web**	**a. February 2007**
b. **Launch for Public Access TV Channel**	**b. September 2007**
20. Smart Parking System (SPS)	
a. **Initial Deployment Phase (*Coaster* rail stations along I-**	**a. July 2008**

I-15 Corridor Assets	Deployment Schedule
5)	b. May 2010
b. **Framework for regional extensibility**	
21. San Diego Performance Measurement System (PeMS)	
a. Freeway	**a. Operational**
b. Arterial	**b. July 2008 – July 2009**
c. Transit	
c1. Framework of functionality	**c1. July 2008**
c2. Initial Deployment	**c2. 2009**
22. VCTMC/Decision Support System (DSS)	**June 2010**
23. Transit Signal Priority on NCTD Bus Route 350 in Escondido (BRT Feeder)	**2008**

The ConOps and SysReqSpec each discuss potential performance measures that will be used to show improved corridor mobility as we previously discussed in Section 3.0. Performance measure objectives, for example, reduction in travel time, increase in travel speeds, reduction in vehicle and person hours of delay, and reduction in incident response and clearance times will be validated by the Stage Two AMS work by initially developing a set of operational scenarios with which to conduct numerous "what-if" tests in the context of both 'with' and 'without' ICMS-related improvements. A comparative analysis will then be performed for each scenario to determine the magnitude and direction of any change in the values for our performance measures. In this way, whether the performance measure objectives are validated will be determined.

Derivable from the I-15 ICMS system concept that we have described in this summary and, in particular, depicted schematically in Figure 3, together with the implementation of additional project investments along the I-15 corridor (Table 3), we expect there to be the following primary benefits from this system:

- Reduced travel times (freeway general purpose lanes, managed lanes, arterials, transit)
- Reduced vehicle and person hours of delay
- Improved level of service (freeway general purpose lanes, managed lanes, arterials)
- Increased travel time reliability
- Reduced incident response and clearance times
- Increased transit ridership

While detailed comparisons between various operational scenarios will be conducted as part of the Stage Two AMS work, at this time we can nonetheless describe at least preliminarily such comparative examinations, which have contributed to an estimation of the significant cost saving factors for ICMS system benefits. Based on output from SANDAG's Regional Transportation Planning Model and from the PeMS system, the ConOps describes (ConOps, Section 3.3, Appendix A) the current state of the I-15 corridor for the freeway, arterial, and transit networks with respect to particular performance measures.

For the freeway network, performance measures include level of service, vehicle hours of delay, bottleneck duration, length of bottleneck vehicle queues, average speed, and number of incidents; for the arterial network, the level of service measure is used for the three primary arterials running parallel to I-15 (Centre City Parkway, Pomerado Road, Kearny Villa/Black Mountain Road); for the transit network, average weekday bus speed, travel times, and ridership are described. In SANDAG's 2030 San Diego Regional Transportation Plan (RTP), comparisons are made among three alternative scenarios for the I-15 corridor ‒ current conditions, with project investments along the corridor including ICMS system operational approaches, and a no-build scenario.

For the I-15 freeway network, improvements were shown to be made under the implementation of the Managed Lanes system that will be one but a key element of the I-15 ICMS system. In essence, we have until now been limited in our estimation of cost saving factors by the use of SANDAG's RTP data and PeMS-related data. This work, however, will be greatly expanded upon during the Stage Two AMS component of the ICM Program.

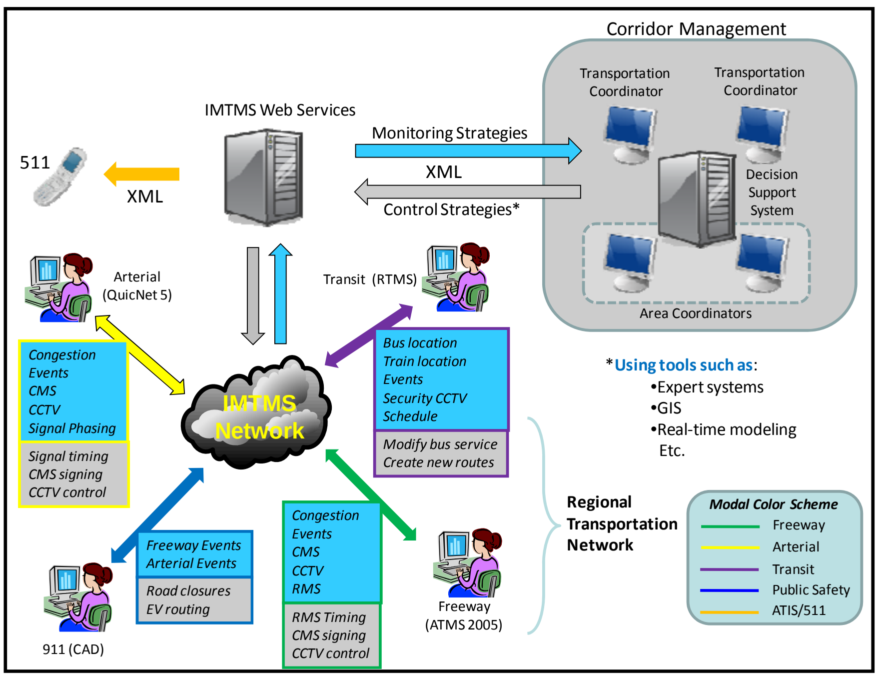

Figure 3: I-15 ICMS System Concept

CHAPTER 5

CONCLUSIONS

The San Diego Pioneer Site's Technical Application demonstrates that the I-15 Corridor is an ideal location to continue with Stage Two of the ICM Program. Moreover, during Stage Two, the strengths of and benefits derived from the I-15 corridor will become ever more evident and continue to be highlighted. San Diego has already invested heavily in the development of this corridor — as well as throughout the region — through its Managed Lanes facility with congestion pricing, bus rapid transit system, 511 advanced traveler information system, unified traffic signal control system, Intermodal Transportation Management System, enhanced data collection for corridor arterials and transit network through development of A-PeMS and T-PeMS, respectively.

Successful collaborative partnerships among transportation and public safety stakeholders have grown stronger as a result of working on Stage One as exemplified by the coordinated response to last fall's San Diego wildfires. These investments coupled with the San Diego Team's continued efforts to enhance already rich data collection and analysis capabilities help make the San Diego I-15 Pioneer Site unsurpassed in its ability to demonstrate and to realize the potential of integrated corridor management. The San Diego team looks forward to building on the commitment of a fully integrated I-15 corridor and to begin developing plans for expanding its I-15 corridor ICMS system region-wide.

APPENDIX A
CONCEPT OF OPERATIONS SUMMARY

A.1 Introduction and Document Contents

The I-15 corridor in San Diego is a model for the multi-modal deployment of the latest and evolving technologies in the region. The region continues to seek the benefits of Intelligent Transportation Systems (ITS) through capital investments in transit, highway, and arterial systems, while focusing on data sharing through early adoption of the Regional ITS Architecture. The San Diego region has a rich history of partnership among the San Diego Association of Governments (SANDAG), its member agencies, and diverse stakeholders, who are all committed to the ICM vision and implementation of the ICMS to support ICM programs.

ICM consists of the operational coordination of multiple transportation networks and cross-network connections comprising a corridor and the coordination of institutions responsible for corridor mobility. ICM programs provide better information, coordination of network junctions, proactive management of capacity and demand, advanced technologies and systems, and improved institutional arrangements. ICMS is a "system of systems," i.e., an transportation management system (TMS) that connects the individual network-based TMS, provides decision support, and enables joint operations according to a set of operational procedures agreed to by the network owners. ICMS facilitates ICM programs to meet corridor needs and realize the ICM vision.

This *Concept of Operations (ConOps)* for an ICMS to be deployed along the I-15 corridor includes the cities of San Diego, Poway, and Escondido. The corridor connects major regional employment centers and interregional goods movement locations. The 21-mile I-15 corridor, including a Managed Lanes section, is already a model for the multi-modal deployment of the latest and evolving technologies for data collection, demand management, and pricing strategies. The region is dedicated to providing additional value from comprehensive approaches to transportation management. The newly implemented 511 advanced traveler information system (511 ATIS) provides corridor users with real-time information and efficient travel alternatives.

This document provides an overview of the San Diego region's ICMS concept, describes current operations in the corridor, how they will function in the near term once the ICMS concept is operational, and identifies current and future responsibilities of San Diego regional stakeholders. By highlighting the flexible and innovative approaches to management along this corridor, the user will understand how improvements currently underway along the corridor serve as a foundation for even further integration in the future. For example, there will be a Bus Rapid Transit (BRT) system along the corridor with BRT stations (called centers) having direct access ramps (DARs) to the Managed Lanes facility and fostered through transit-oriented developments. The centers will include an array of ITS elements such as real-time arrival information, trip planning kiosks, smart card electronic payment devices for pre-boarding payment, and smart parking technologies to allow for posting of space availability and reservations.

The successful implementation of the ICMS and concepts requires a proactive, strategic, and collaborative approach to public and private-sector stakeholder partnerships, along with a history of successful joint operation initiatives, both of which have been achieved under the institutional umbrella of SANDAG. The Virtual Corridor Transportation Management Center (VCTMC) outlined in this document will allow for the coordination among multiple agencies on multiple levels for data collection and processing, data sharing, and decision support based on workflow and on an expansion of available information.

By providing a user-oriented view of the potential for integrated management along the I-15 corridor, the ConOps focuses on the corridor's needs and problems, goals and objectives, proposed operational approaches, and strategies for attaining these goals, the institutional framework in which the ICMS will operate, and the associated operational, technical, and institutional issues that must be addressed in the future. SANDAG's partnerships can fully capitalize on existing technologies to design and implement model deployment and technology transfer initiatives to dramatically improve corridor mobility and productivity along the I-15 corridor.

A.2 Development of the I-15 ConOps

The development of the ConOps for the San Diego I-15 ICMS is an important step in the overall process to plan and implement integrated corridor management for the corridor. The development and implementation of the I-15 ICMS system follows the principles of "systems engineering," which is a formal process to help develop a system of higher integrity, reduce the risk of schedule delays and cost overruns, ensure better system documentation, and promote a higher level of stakeholder participation. The systems engineering process is shown as a "V" diagram below in Figure 1-1 as a way of relating the different stages in the system life cycle to one another. As shown in the diagram, the ConOps is a relatively early activity in the overall systems engineering process.

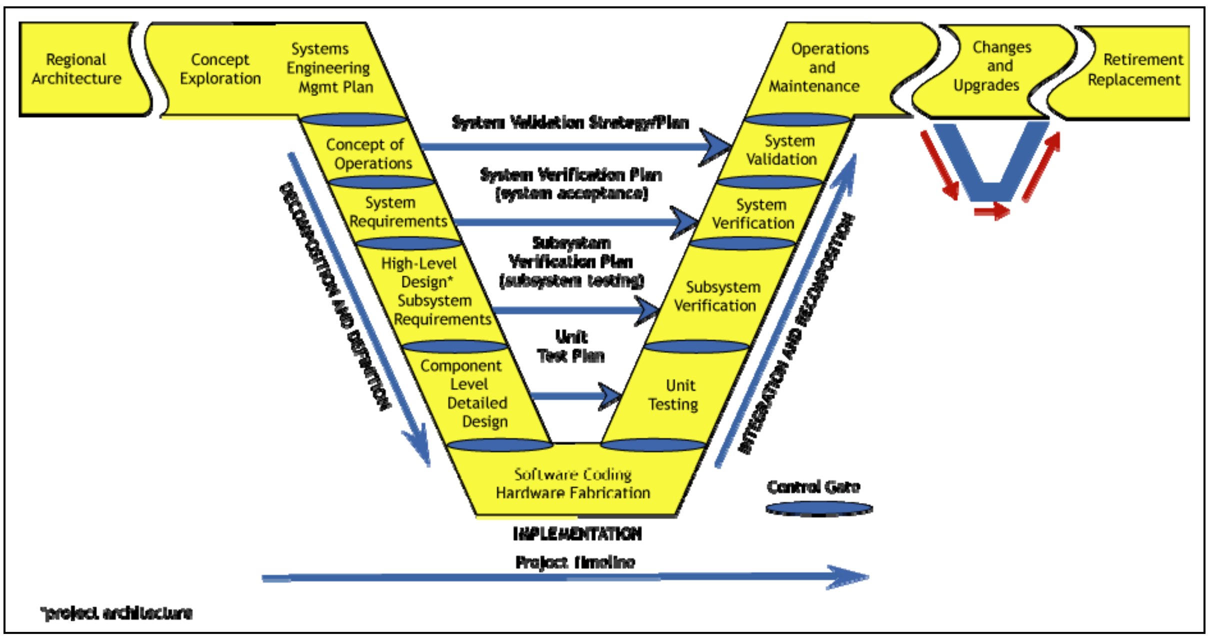

Figure 1-1. Systems Engineering Process ("V" Diagram)

The I-15 ICMS ConOps is essentially a user-oriented perspective of integrated corridor management for the corridor, and thus, corridor stakeholders play the primary and invaluable role in its development and mark the initial milestone along the road to I-15 ICMS implementation for the corridor's stakeholders. The development of the ConOps has, in essence, been the first test of institutional coordination and integration for the I-15 corridor stakeholders and because of the history and strong foundation that these stakeholders have in successfully working together under the leadership of SANDAG, the stakeholder team moved efficiently through the ConOps development task.

The ConOps document lays out the I-15 ICMS concept, explains how things are expected to work once it is in operation, and identifies the roles and responsibilities of the various stakeholders to make this happen. The ConOps answers the following set of core questions:

- Why: Justification for the system, identifying what the corridor currently lacks, and what the system will provide
- What: Currently known elements and the high-level capabilities of the system
- Where: Geographical and physical extents of the system
- Who: Stakeholders involved with the system and their respective responsibilities
- When: Time sequence of activities that will be performed
- How: Resources needed to design, build, operate, and maintain the system

The ConOps does not delve into technology or detailed requirements of the ICMS, but it does address the operational scenarios and objectives, information needs, and overall functionality. The ConOps must also address the "institutional" environment in which integrated corridor management must be deployed, operated, and maintained.

Table 1-1. Layout ICMS Concept of Operations

1. Scope and Summary: I-15 ICMS Corridor in San Diego
- 1.1 Introduction and Document Contents
- 1.2 Development of the ConOps
- 1.3 Corridor Boundaries, Networks, and Stakeholders
- 1.4 Corridor Operating and Institutional Conditions
- 1.5 Issues, Needs and Potential for Integrated Corridor Management
- 1.6 Vision, Goals, and Objectives
- 1.7 Concept Operational Description: Approaches and Strategies
- 1.8 Required Assets, User Needs, and ICMS Implementation Issues
- 1.9 Concept Institutional Framework

2. References

3. Existing I-15 Corridor Scope and Operational Characteristics
- 3.1 Corridor Boundaries and Networks
- 3.2 San Diego ICMS Corridor Stakeholders and Institutional Partners
- 3.3 Operational Conditions of the San Diego ICMS Corridor and Associated Networks
- 3.4 Existing Network-Based Transportation Management and ITS Assets
- 3.5 Proposed Near-Term Network Improvements
- 3.6 Current Network-Based Institutional Characteristics
- 3.7 Regional Architecture Review
- 3.8 Problems, Issues, and Needs for the San Diego I-15 Integrated Corridor and Associated Networks
- 3.9 Potential for an Integrated Corridor Management System
- 3.10 Vision for San Diego I-15 Integrated Corridor Management System

4. San Diego I-15 ICMS Operational Concept
- 4.1 Goals and Objectives
- 4.2 ICMS Approaches and Strategies for the San Diego I-15 Corridor
- 4.3 ICMS Asset Requirements and User Needs
- 4.4 Comparison of ICMS Asset Requirements with Current and Planned Assets
- 4.5 Operational Description of ICMS Concept (High-Level/General)
- 4.6 Alignment with Regional Architecture
- 4.7 Implementation Issues
- 4.8 Institutional Framework
- 4.9 Performance Measures for Evaluation of San Diego ICMS Operations

5. Operational Scenarios
- 5.1 Daily Operations
- 5.2 Freeway Incident
- 5.3 Arterial Incident
- 5.4 Transit Incident
- 5.5 Special Event
- 5.6 Major Disaster

A.3 Corridor Boundaries, Networks, and Stakeholders

The I-15 ICMS corridor is a 21-mile segment of I-15 in San Diego County that currently includes an 8-mile Managed Lanes facility. This corridor is a regionally significant segment of I-15 from State Route (SR) 52 in the City of San Diego to SR 78 in the City of Escondido. It also includes the portion of SR 163 from SR 52 to I-15 in the City of San Diego. This Managed Lanes corridor is a critical component of I-15 as one of the two primary north-south transportation corridors in San Diego County. I-15 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. It encompasses three cities (San Diego, Poway, and Escondido). The I-15 corridor is situated within a major interregional goods movement corridor connecting Mexico with Riverside and San Bernardino counties, as well as Las Vegas, Nevada.

The I-15 Managed Lanes corridor is currently an eight- to ten-lane freeway within the corridor boundaries, with additional auxiliary lanes throughout the corridor. Within the median of I-15 from SR 163 to SR 56 is a two-lane reversible, high occupancy toll (HOT) facility. Known locally as the I-15 Express Lanes, this eight-mile, barrier-separated facility operates in the southbound direction during the a.m. peak period, northbound during the p.m. peak period, and all day (northbound) during the weekend.

The corridor is in the jurisdiction of SANDAG, the California Department of Transportation (Caltrans) District 11, and the cities of San Diego, Poway, and Escondido. Partnerships also exist with the transit agencies: Metropolitan Transit System (MTS) and North County Transit District (NCTD) to operate services along the corridor. The corridor includes the following networks:

- I-15 Freeway Network operated by Caltrans with agreements with the California Highway Patrol (CHP) for incidents and SANDAG for the value pricing program. It includes four to five lanes in each direction, including a two-lane reversible HOT facility operating during peak periods (and all traffic during non-peak hours) and a more extensive Managed Lanes facility currently under construction.
- Arterial Network that encompasses the cities of San Diego, Poway, and Escondido. Each city's public works/transportation department operates the three arterial links identified as candidates to carry excess capacity in their jurisdiction: Kearny Villa Road/Black Mountain Road (7 miles), Pomerado Road (13 miles); and Centre City Parkway (6 miles). Additionally, there are secondary parallel routes that can be used in the case of emergencies.
- Transit Network that includes express bus service into San Diego operated by MTS and local service operated by NCTD and San Diego Transit. BRT service will be operational with the Managed Lanes system and will include service from three stations along the corridor functioning as a rail system.

The I-15 corridor stakeholders are instrumental in the development of the ConOps and associated projects along the corridor. Additional stakeholders will be involved along each arterial, as appropriate.

I-15 Corridor Stakeholders

- San Diego Association of Governments (SANDAG) (including the San Diego Traffic Engineers' Council (SANTEC), and Intelligent Transportation Systems Chief Executive Officer (ITS CEO) Group
- California Department of Transportation (Caltrans)
- California Highway Patrol (CHP)
- Metropolitan Transit System (MTS)
- North County Transit District (NCTD)
- San Diego County Service Authority for Freeway Emergencies (SD SAFE)City of San Diego

- City of Poway
- City of Escondido
- County of San Diego Office of Emergency Services (OES)
- Department of Homeland Security (DHS)
- Federal Highway Administration (FHWA)
- Federal Transportation Administration (FTA)

Corridor Operating and Institutional Conditions

The I-15 corridor serves as the primary artery for the movement of commuters, goods, and services from inland northern San Diego County to downtown San Diego and two burgeoning employment centers located at the midpoint of the corridor. The corridor also serves a growing number of interregional trips, composed increasingly of employees who work in the greater San Diego region, but who are finding affordable housing outside of the region in neighboring Riverside County to the north. The I-15 general purpose lanes and I-15 express lanes are experiencing increasing levels of congestion during ever-lengthening peak travel periods, while travelers are incurring commensurate increases in trip delays. For example, the following characteristics are currently observable on the corridor.

- Corridor bottlenecks include the SR 163 junction, the SR 56 interchange, the SR 78 interchange, and the Lake Hodges Bridge
- Travel times for northbound travelers increase by 50 percent during the p.m. peak travel. Travel times in the southbound direction have increased by 400 percent.
- The express bus service operates currently in the HOT lanes on the corridor. Average weekday speed is 26 mph. The addition of the Managed Lanes/BRT system will increase the capacity and performance.
- The I-15 Reversible Lanes have noticeably reduced congestion in the South Segment of the corridor for both a.m. and p.m. peak periods.

When incidents or heavy congestion occur on the I-15 within the corridor, historical data show that travelers will use alternate arterial routes. These decisions are based on traveler experience and knowledge of typical arterial travel times or incident-bypass capability.

In terms of the institutional context, the following lists improvements that are categorized by network and responsible agency:

- SANDAG – 511; inter-agency coordination between freeway and transit systems.
- Caltrans, District 11 ─ Implementation of Managed Lanes along the I-15 corridor with reconfigurable lanes and multiple exit/entry points; new fiber optic network; upgrades to the freeway management system surveillance capabilities that include more detectors and full-coverage, closed-circuit television (CCTV); revised and upgraded incident management procedures for automated detection and response (including expanded freeway service patrols); changeable message signs (CMS) at additional locations along the freeway; upgrading of the I-15 Reversible Lane Control System (RLCS) on the south segment.
- Cities of San Diego, Poway, and Escondido ─ Implementation of QuicNet 4+ traffic signal control system for inter-jurisdictional signal coordination along major arterials; implementation of Intermodal Transportation Management System (IMTMS) regional integrated workstations in city traffic engineering departments.

- NCTD (rail) and MTS (bus) ─ New BRT service along the I-15 corridor as part of the Managed Lanes project; smart card system on the buses and at the train stations for transit fares; new SPRINTER light rail system; in-terminal/wayside system (e.g., next train arrival) at all SPRINTER stations and platforms; improved public address (PA) systems for in-vehicle annunciation and in-terminal announcements.

The agency-specific strategies, systems, and networks benefit individual networks. While there is a history of cooperation in the San Diego region, many decisions are still made by individual agencies. The following are examples where independent systems exist and can be improved with integrated management.

- Continuous count and occupancy data is not provided for each arterial.
- Traveler information (511 and http://www.511sd.com/) is new and has not included all pre-trip information yet.
- Real-time information for route and modal shifts is not available yet.
- Access to high occupancy vehicle (HOV)/HOT lanes is limited.
- Advanced travel information is minimal.
- Park and Ride facilities are at or near capacity.
- Express bus service is not fully developed.

The agency-specific systems, strategies, and technologies provide benefits primarily in their individual networks. Since the corridor encompasses multiple agencies, jurisdictions, and travel modes in areas where there are cooperative agreements and systems in place, the region offers expanded opportunities. The Transportation Committee at SANDAG functions in a coordinating capacity and serves as a model for institutional partnerships. In addition, special task forces and coordination mechanisms have been established for special events.

The I-15 corridor is also part of the development of the San Diego regional ITS architecture in which the I-15 corridor stakeholders fully participated. The existing and proposed functionality of the regional architecture includes the following:

- An Intermodal Transportation Management System that integrates freeway data from the Caltrans Advanced Traffic Management System (ATMS) 2005 and the Regional Transit Management System. Arterial data is due to be added later in 2007.
- Real-time information sharing between all agencies and providing a clearinghouse of real-time information covering all critical routes and modes and implementation of center-to-center linkages and storage capabilities. Inclusion of ITS standards as developed by US DOT.
- Coordination and support between transportation and public safety agencies, including integration on the corridor for major incidents, construction, special events, and daily operations.
- A regional 511 system became operational in February 2007. SANDAG has contracted the 511 Information Service Provider (ISP) as the portal operator. Data for the 511 system comes from the IMTMS system, which acts as a clearinghouse for freeway and transit data now and in the future will include arterial congestion and incident data.
- A regional payment/financial clearinghouse, by which the same fare payment smart card can be used to pay transit fares in the region.
- Inclusion of emergency management agencies for the purpose of inputting arterial incidents and informing them of real-time freeway and transit conditions.

A.4 Issues, Needs, and Potential for Integrated Corridor Management

The I-15 corridor stakeholders discussed the ICMS through the various networks and associated systems that comprise the current corridor. Using available technologies, they can be integrated further. The issues of congestion and capacity can be addressed through the planned Managed Lanes facility and associated BRT stations and routes and coordination with arterial networks.

The stakeholders in the San Diego region are focusing on the operation, institutional, and technical coordination of transportation networks and cross-network connections throughout the corridor. The ICMS concept will address the issues and needs identified by the stakeholders.

Table 1-2. San Diego I-15 Corridor Issues and Needs

Congestion and Capacity—

- **Issue: Increasingly congested conditions on I-15**
- **Issue: Increasingly congested conditions on corridor's arterial network**
- **Issue: Park and Ride facilities are not sufficient**

Transit—

- **Need: Improved transit reliability**
- **Need: Real-time, comprehensive, accurate information to travelers**
- **Need: Frequent service**

Need: Competitive service

Transportation System Management—

- **Issue: Managing traffic flow between I-15 freeway ramps and adjacent arterials with ramp metering**
- **Issue: Managing traffic flow on I-15 (general purpose/managed lanes)**
- **Issue: Limited access to HOV/HOT facilities**
- **Issue: Coordination across multiple functional systems**

Traveler Information Services—

- **Issue: Minimal ATIS coverage of the corridor**

Inter-organizational Coordination—

- **Need: Inter-jurisdictional and inter-organizational coordination and integration among corridor stakeholders**
- **Need: Exchange and sharing of real-time data**
- **Need: Improved response times to non-recurring incidents**

A.5 Vision, Goals, and Objectives

The vision statement for the I-15 corridor was developed with the San Diego region stakeholders. This statement reflects current practices, planned improvements, and future scenarios.

- Within approximately the next five years, the corridor will give travelers the opportunity to make seamless and convenient shifts among modes and among the corridor's networks to complete their trips. Enhanced mobility for people, goods, services, and information will be achieved by further enhancing current levels of existing interoperability between field elements and through continued collaboration and cooperation among the corridor's institutional partners and their native functional environments or systems.
- The ICMS is therefore focused on improving person- and vehicle-throughput, productivity, connectivity, safety, environmental compatibility, and enhancing accessibility to reach destination points in a reliable and timely manner.

Using this vision as a starting point and taking into account the I-15 corridor specifics, the stakeholders developed a list of goals and objectives detailed in the following table. The stakeholders produced five goals and associated objectives covering the following primary topics. These take into account the traveler's experience on the corridor.

Table 1-3. I-15 ICMS Corridor Goals and Objectives

Goals	Objectives
The corridor's multi-modal and smart-growth approach shall improve accessibility to travel options and attain an enhanced level of mobility for corridor travelers.	▪ Reduce travel time for commuters within the corridor ▪ Increase transit ridership within the corridor ▪ Increase the use of HOVs (carpools and vanpools) for commuters ▪ Increase person and vehicle throughput within the corridor on general purpose and managed lanes ▪ Increase person and vehicle throughput on arterials ▪ Reduce delay time for corridor travel on the corridor's networks (e.g., I-15 and arterials) ▪ Increase percentage share of telecommuters from corridor commuter market ▪ Increase the use of established and effective TDM programs ▪ Promote development to encourage the use of transit
The corridor's safety record shall be enhanced through an integrated multi-modal approach.	▪ Reduce incident rate ▪ Reduce injury rate ▪ Reduce fatality rate ▪ Reduce roadway hazards

Table 1-3. I-15 ICMS Corridor Goals and Objectives (cont'd)

Goals	Objectives
The corridor's travelers shall have the informational tools to make smart travel choices within the corridor.	▪ Improve collection and dissemination of arterial network information ▪ Collect and process data on the operational condition/status of all corridor networks, including ‣ Comparative travel times between major origins and destinations ‣ Construction, detours, and other planned road work ‣ Occurrence and location of incidents ‣ Expected delays ‣ Number of parking spaces available at Park an Ride lots/structures ▪ Disseminate, in a multi-lingual fashion, comprehensive, real-time, and accurate information to travelers within the corridor by means of multiple media (e.g., phone, computer, PDA/Blackberry, TV, CMSs, 'Next Bus' informational signs) ▪ Make available archived historical data to travelers ▪ Achieve a high level of 511 call volume and Web use ▪ Achieve high overall satisfaction with 511 system
The corridor's institutional partners shall employ an integrated approach through a corridor-wide perspective to resolve problems.	▪ Improve level of institutional coordination among stakeholders by leveraging off of and modifying existing agreements among the partners to accommodate the needs of the I-15 corridor ▪ Strengthen existing communication linkages among all Corridor institutional stakeholders and establish new communication linkages where appropriate (e.g., business/industrial parks along the corridor) ▪ Enhance the regional/joint operations concept throughout the corridor ▪ Balance the needs of through traffic and local communities by coordinating construction and overall mitigation management on I-15 and arterials
The corridor's networks shall be managed holistically under both normal operating and incident/event conditions in a collaborative and coordinated way.	▪ Establish/enhance joint agency action plans to respond to congestion especially at I-15/arterial network interfaces and at the Lake Hodges chokepoint ▪ Develop/improve methods for incident and event management (e.g., data sharing) ▪ Reduce overall incident clearance time ▪ Identify means of enhancing corridor management across all networks (e.g., implement transit signal priority on selected components of arterial network)

These goals and objectives form the basis for developing the ConOps scenarios. They enable the current and future corridor characteristics to be evaluated based on the needs identified by the stakeholders in the region.

A.6 ICM Operational Concept Description: Approaches and Strategies

In the future, the I-15 ICM will provide, to the greatest extent possible, efficient and reliable travel throughout the corridor and the constituent networks, resulting in benefits to corridor travelers in terms of, for example, improved and consistent trip travel times and real-time traveler information. Using cross-network strategies, the corridor will capitalize on integrated network operations to manage the total capacity and demand of the system in relation to the changing corridor conditions. The stakeholders identified several ICM strategies based on the I-15 corridor goals and objectives. They are categorized as follows.

- Share/Distribute Information: manual information sharing, information clearinghouse/information exchange network between corridor networks and agencies; 511 (pre-trip traveler information); en-route traveler information (smart signage and smart parking); access to corridor information by ISPs and other value-added entities; automated information sharing (real-time data); and common incident reporting system and asset management system.
- Improve Junctions/Interfaces: signal pre-emption – identifying "best route" for emergency vehicles; multi-modal electronic payment; signal priority for transit, bus priority on arterials; transit hub connection protection; multi-agency/multi-network incident response teams/service patrols; and training exercise.
- Accommodate/Promote Network Shifts: modify ramp metering rates to accommodate traffic (including buses) shifting from arterials; promote route shifts between roadway and transit via en-route traveler information devices; promote shifts between transit facilities via en-route traveler information devices; congestion pricing for managed lanes; and modify arterial signal timing to accommodate traffic diverted from the freeway.
- Capacity/Demand Management (short-term): land use control; modify HOV restrictions; increase roadway capacity by opening HOV/HOT lanes/shoulders; scheduled closures for construction; coordinate schedule maintenance and construction activities among corridor networks; planned temporary addition of transit capacity; and modify parking fees (smart parking).
- Capacity/Demand Management (long-term): peak spreading; ridesharing programs; expand transit capacity; and land use around BRT stations.

Some of these strategies appear to be mode-focused because actions are to be taken by an individual agency on one network; however, such actions under ICM also consider conditions on other networks. Moreover, corridor agencies will rely on ICMS to provide decision support for such actions.

By implementing the corridor wide ICM strategies, the I-15 corridor has the potential to enhance current and near-term operations. By working together on such strategies, the stakeholders in the San Diego region can succeed in realizing these enhancements along the corridor.

The daily operation of the corridor will be similar to the transportation and public safety command center model (i.e., Mission Valley East pilot) that has been used for major special events (e.g., Super Bowl XXXVII in 2003 in San Diego), but will now be applied on a permanent basis for day-to-day transportation operations. This will be accomplished via a Virtual Corridor Traffic Management Center (VCTMC) operating among the corridor agencies. This VCTMC will operate the ICMS as a "sub-regional" system, managing the various networks and influencing trips that use the corridor. The VCTMC is run by a coordinator jointly appointed by collaborating agencies. While the City of San Diego, MTS, and Caltrans may provide dedicated support staff and co-locate them, other agencies may provide remote or virtual support with existing staff on a non-dedicated basis.

All operations among corridor networks and agencies (e.g., activation of specific ICMS strategies) will be coordinated by the VCTMC. The VCTMC will investigate and prepare corridor response plans for various scenarios that can be expected to occur within the corridor.

The VCTMC operates over the infrastructure of the IMTMS. Voice, data, video, information, and control will be provided to all agencies based on the adopted protocols and standards for the sharing of information and the distribution of responsibilities. The VCTMC will monitor corridor travel conditions 24 hours a day/7 days (24/7) a week and use the response plans, real-time information, and the implemented corridor strategies to address any conditions that present themselves. All supporting staff will know their respective roles and responsibilities and will be aided, when available, by response plans and ICMS decision support software. Moreover, the coordinator will be able and authorized to improvise as situations may dictate.

Corridor-based traveler information will be made available on 511, Web sites, CMSs, and through the media and ISPs, presenting corridor trip alternatives complete with current and predicted conditions. Travelers will access or be given real-time corridor information so they can plan or alter aspects their trips such as mode, route choice, or departure time in response to current or predicted corridor conditions.

Each traveler will be able to easily make route and modal shifts between networks due to integrated corridor information, integrated fare/parking payment system, and coordinated operations between networks. Travelers will be able to educate themselves about the corridor so they can identify their optimal travel alternatives and obtain the necessary assets (e.g., smart card, available parking) to facilitate their use of corridor alternatives when conditions warrant.

A.7 Required Assets, User Needs, and ICMS Implementation Issues

The various stakeholders within the I-15 corridor have developed a number of assets to improve performance along the I-15 corridor. They have implemented a variety of policies, strategies, and ITS technologies and have identified where assets can be added in the near term.

The following assets, which are currently implemented or are under development/construction, are critical for the San Diego I-15 corridor:

- 511 ATIS, launched in February 2007
- IMTMS, implemented in June 2006
- Performance Measurement System (PeMS)
    - Freeway PeMS is already operational
    - Arterial PeMS, is scheduled for an August 2008 implementation
    - Transit PeMS is scheduled for an August 2008 implementation
- Region-wide adoption of QuicNet 4 (and its upgrade to QuicNet 4+) traffic signal control platform
    - Pilot Implementation Phase (QuicNet 4+ with Caltrans, San Diego, and Chula Vista): July 2008
    - Integration of QuicNet 4+ into the IMTMS environment: January 2009
    - Full Implementation Phase (regionalization of QuicNet 4+): March 2009
- Managed Lanes, together with Value Pricing, currently under phased construction:
    - Middle Segment (July 2008 – January 2009 in a phased implementation)
    - North Segment (January 2012)
    - South Segment (January 2013)

- BRT with DARs is currently under phased construction in accordance with the Managed Lane construction schedule

The three most important additions to ICMS assets with current expected completion dates are the following:

- VCTMC/Decision Support System, with completion date of June 2009 to coincide with Phase III demonstration of the ICM Program
- Transit signal priority on NCTD Bus Route 350, a bus feeder for BRT system, 2008
- Improved data collection, incident reporting, and data archiving for arterials
  - Pilot Phase, June 2008
  - Full implementation (ICM Phase III Demonstration), June 2009

The stakeholders suggested that a VCTMC be established to take a lead role in corridor management. This center would enable further integration of ICMS functions. In order to establish this center, current operational agreements could be amended. For example, operational agreements have recently been established between institutional partners for the Mission Valley Event Management project. Similar agreements can be established for the I-15 corridor management and provide a platform for the VCTMC operation. VCTMC would take advantage of the information sharing infrastructure provided by the IMTMS.

Transit signal priority reduces transit vehicle travel time and improves reliability. Although the region wide adoption of QuicNet 4 traffic signal control platform makes it less complicated for cross-jurisdictional coordination, transit signal priority has yet to be deployed on arterials in the corridor.

Improved data collection and traffic monitoring are needed on the I-15 corridor arterials. Traffic count stations need to be installed at several locations on key parallel arterials in the cities of San Diego, Poway, and Escondido. Assuming these stations are constructed as part of the I-15 ICMS project, the cities' current staff will be able to operate these stations as part of their daily tasks. The traffic data (volume and speed) will be linked directly to the main Transportation Management Center ((TMC) Caltrans) and the cities' TMCs. The traffic data from the local arterial, combined with the data from the freeway, can be used to trigger specific timing plans. The data transfer from the count stations to the nearest traffic signal will be either hard-wired or wireless. From the traffic signal the data will transferred via fiber signal communication cable to cities' TMC where the QuicNet 4 is located. The Regional Arterial Management System connects Caltrans TMC to the cities' QuicNet 4.

Based on the development of our ICMS concept and its operational description, the following implementation issues have been identified by the I-15 corridor stakeholders. These issues comprise technical, operational, and institutional components of the I-15 ICMS concept.

Technical Issues

- Data archiving and accessibility for future analyses
- Modifying/updating San Diego regional ITS architecture to bring it into alignment with the I-15 ICMS concept
- Use of regional transit fare system (*Compass Card*) across multiple transit service providers
- Expansion of functionality for 511
- Ensuring quality, frequency, and accuracy of information

Operational Issues

- Enhancing transit capacity in response to accidents
- Implementing bus signal priority for transit on arterials
- Coordinating different operating systems across agencies to work together (e.g., I-15 freeway on-ramp metering signals with adjacent arterial traffic signals)
- Fully integrating commercial vehicle operations into I-15 the ICMS concept

Institutional Issues

- Establishing policies and arrangements with private entities (parking, information service providers, and major employment centers along the I-15 corridor)
- Compatibility of VCTMC responsibilities for I-15 ICMS corridor stakeholders with their conventional responsibilities
- Expansion of set of organizational stakeholders as part of the I-15 ICMS team beyond those that are only transportation-focused
- Enhanced level of inter-organizational coordination and integration among stakeholders

The stakeholder agencies have already implemented various polices, strategies, and ITS technologies to improve performance along the I-15 corridor. These assets can be enhanced to implement and meet the corridor goals and objectives. The table on the following page outlines some of these assets.

Based on the development of our ICMS concept and its operational description, the following set of User Needs (Table 1-4) has been developed by the I-15 corridor stakeholders. This set of User Needs is complete and appropriate for the I-15 ICM operational concept and that the planned I-15 ICM system must satisfy. The User Needs describe the operational functions of the proposed I-15 ICMS based on our vision, goals, and objectives for the system. Subsequent to development of the ConOps is the development of specific requirements for the I-15 ICM system, and these requirements will be explicitly derived from this set of User Needs.

Table 1-4. I-15 ICMS User Needs

ID No.	Title	Description/Rationale
1	Access/store config Data	This User Need provides for the creation and management of a configuration database instance that maintains static information on various parameters within the I-15 corridor.
2	Collect and Process Data	This User Need is the core service of ICMS that supports most of the system functionality. Data is collected from a variety of existing and planned systems according to Interface Control Documents, some of which need to be developed as new systems come on line. Once data is collected, certain processing algorithms are invoked that provide a higher level of information aggregation (e.g. volumes, occupancies and speeds at multiple locations are converted to travel times). Process Data function also includes conversion of host system data formats to standard XML schema for publishing information across the ICMS system.
3	Access/Store ICMS Historical Information	This User Need provides the capability to create and populate a historical database instance. This database contains real- time information on corridor performance as derived from data collected in the Collect and Process Data User Need. Accessing existing historical databases in ATMS 2005, RTMS and RAMS is an important function of this User Need. Having consistent export formats for data from these historical databases would simplify corridor-wide analysis. Ad hoc reporting based on this historical data allows the system users to create a variety of reports that characterize corridor operations and performance. These reports can then be stored in the ICMS historical database.
4	Publish Information to System Managers	This User Need that disseminates ICMS data from all sources to agencies that manage one or more modes in the integrated corridor network: freeway, arterial, transit, public safety, commercial vehicles. This information is differentiated from the information published to system users.
5	Interactively Conference with Multiple Agencies	This User Need that allows system managers to directly collaborate in real-time prior to, during or after a major event in the I-15 Corridor. A variety of voice, video and data formats will be supported for multi-site collaboration.
6	Display Information	This User Need covers the ability to take information produced by ICMS and its subsystems and display a variety of data formats in a form that agency decision-makers can use to visualize corridor operations, make decisions and take actions to implement the various decision components.

7	Coordinate Transportation and Public Safety Operations	This User Need is another core need for the I-15 ICMS because it addresses major institutional issues in getting the transportation and public safety communities to work closer together. This is accomplished by providing public safety users the multi-dimensional data inherent in transportation management systems while at the same time seeking technical solutions to extracting useful incident information from public safety CAD systems.

Table 1-4. I-15 ICMS User Needs (cont'd)

ID No.	Title	Description/Rationale
8	Share Control of Devices	This User Need allows agencies to remotely control selected functions of field devices regardless of location or agency ownership. For this User Need to become real there must be interagency agreements to allow such sharing under carefully defined conditions.
9	Manage Video Imagery	The San Diego region has a variety of video sources that provide a critical view of emerging and on-going events. These video sources can produce aerial, snapshot, archived clips and real-time imagery to a wide variety of system users via high-bandwidth links.
10	Respond to Corridor Planned and Unplanned Events	This User Need allows ICMS users and Corridor Managers to use some form of decision tool that fuses real-time data and manually-entered data derived from field communications at the event site (e.g. CHP Traffic Officers talking to dispatchers using the CHP radio system). The response plan is then either manually or automatically generated based on the fused data input. Once a response plan is generated, the system operator can review the plan's components and make changes as deemed necessary before transmitting plan components to the affected systems. The status of affected systems is then returned to the ICMS operator and logged in the historical database.
11	Assess Impact of Corridor Management Strategies	This User Need allows corridor managers to model various traffic and service management strategies for the corridor to gauge the impact of these strategies on corridor performance. The intent of this User Need is to model strategies and to return results within a time frame suitable to affect decision-making during a major event in the corridor. The impact results will be displayed to corridor managers in both 2D and 3D formats. This User Need will also be invoked for longer- term assessments.
12	Publish Information to System Users	This is the information dissemination User Need counterpart to User Need 4. This provides corridor information to the regional 511 system where it will be further disseminated to various classes of system users across a variety of media. This User Need will also make available a standard XML data stream and video imagery to other entities for dissemination to system users as SANDAG policy determines (e.g. direct feeds to the media).
13	Measure Corridor	Measure Corridor Performance User Need looks at multi-modal corridor data from both a short-term and long-term perspective. Existing historical

	Performance	**databases for ATMS 2005, RTMS, RAMS, CAD systems, CPS and Smart Parking provide mode-specific data. Likewise PeMS provides a traffic and transit operations view of data. Based on these data sources, corridor demand will be analyzed using actual data or by demand modeling techniques. Using stored corridor configuration data, excess corridor capacity can be measured for any desired time period. This User Need will be most valuable for long-term corridor management.**
14	**Manage Corridor Demand and Capacity to Optimize Long-Term Performance**	**Capacity/Demand Management User Need provides the ability for corridor managers to collaboratively develop longer-term corridor management strategies. These strategies include both capacity and demand management strategies. For example, a classic demand management strategy is ramp metering. A classic capacity management strategy is managed lanes. The goal of this User Need is to increase total corridor performance in the long-term by optimal balancing of capacity and demand.**
15	**Measure System Performance**	**Measure System Performance User Need provides for constant monitoring of field devices, server systems and communications networks needed to support the various integrated corridor management functions. Based on monitored data, metrics for system components such as reliability and availability will be measured and stored in the ICMS historical database.**
16	**Manage ICMS System**	**System Management User Need is the administrative function of ICMS. Data management for ICMS configuration data, user account management incorporating system-wide security functions and IT- centric functions such as data backup and archival are included within this User Need.**
17	**Document System and Train System Users and Maintainers**	**Documentation and Training User Need provides logistical support to the ICMS system through documentation and training.**

A.8 Concept Institutional Framework

The management and operation of the I-15 corridor and the ICMS will be a joint effort of all of the stakeholders. In San Diego, a structure already exists that can be utilized for this operation.

SANDAG's Transportation Committee is a standing committee responsible for policy direction and review. It comprises the current stakeholders, as well as community representatives.

The **ITS Chief Executive Officer (CEO) Group** will be established as a subset of the Transportation Committee in order to manage specific functions on the I-15 corridor. This group will build on current inter-agency agreements, operational policies and procedures, and overall administration.

The **ITS CEO Group** provides executive oversight and policy for the region's ITS program. Participants include the chief executive officers from SANDAG, Caltrans, MTS, NCTD, and the Mayor's representative from the City of San Diego. This working group provides a forum for the executives to discuss strategy, address problem resolution, receive status reports, and provide direction to ITS project managers. New projects and potential grant proposals also are proposed to key executives at this meeting for partnership discussion and commitment.

To support the ITS CEO Group, the **Regional Architecture Committee** will work closely with the **I-15 Corridor Management Team** to promote corridor-based coordination throughout the San Diego region.

Current members will participate in the **VCTMC**. They will be responsible for the daily operations of the I-15 ICMS corridor. This center will start by coordinating activities of the I-15 corridor, but will be tasked with future coordinated operations opportunities, such as corridor management systems in other corridors. The VCTMC will ensure consistency with the Regional ITS Architecture and operating procedures and policies, as well as coordinate operational functions.

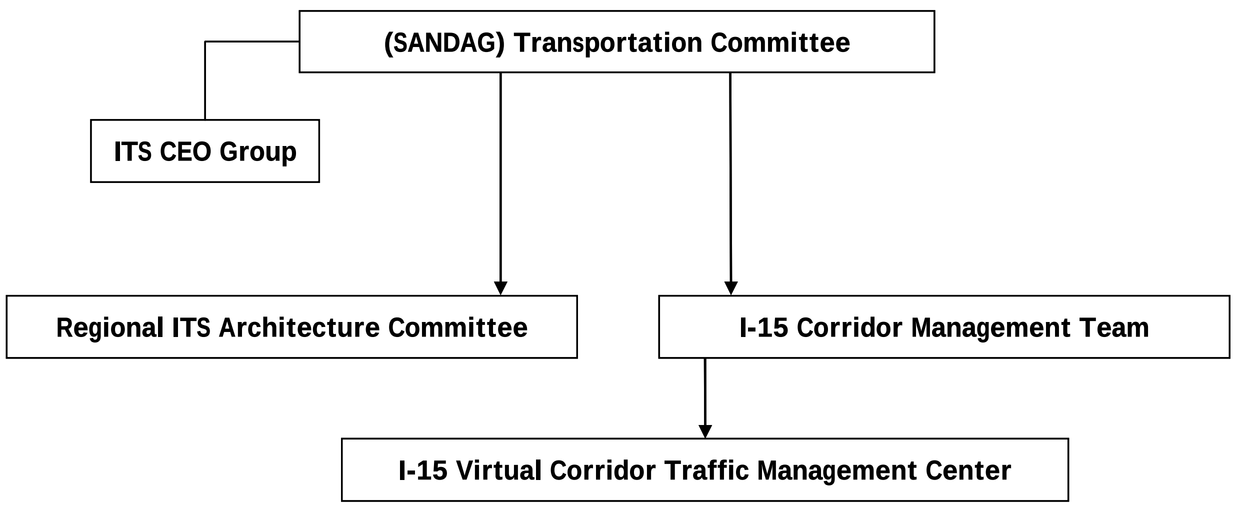

Figure 1-2. Institutional Framework for the I-15 ICMS

SANDAG's committee structure provides the backdrop for the I-15 ICMS institutional framework. Overall, these committees provide opportunities for involvement in regional programs by citizens, elected officials, agency staff, and representatives of civic and community groups. The I-15 Corridor Management Team will be the primary decision-making body for the I-15 ICMS corridor and will consist of leadership-level representatives from each of the stakeholders in the I-15 ICMS corridor. Members of the team will manage the distribution of responsibilities, the sharing of control, and related functions among the corridor partners. The I-15 Corridor Management Team will be responsible for establishing the necessary inter-agency and service agreements, budget development, project selection and initiation, corridor operational policies and procedures, and overall administration.

The Regional ITS Architecture Committee, which maintains the San Diego regional ITS architecture, will ensure that this concept is consistent with the regional architecture. Its responsibilities will expand to promote coordinated operations within the various corridors that make up the region, as well as addressing any "inter-corridor" operational issues (i.e., be the coordinator of multiple corridor operation panels and ICMS).

Each of the I-15 ICMS corridor partners will have specific responsibilities they will perform as part of ICMS operations. The VCTMC will leverage staff off of existing positions held at I-15 stakeholder agencies. This virtual center will enable primary stakeholders, as well as other organizations (i.e., local law enforcement and emergency personnel) to participate.

The VCTMC will enable the I-15 corridor to be managed as an integrated transportation system. The goals and objectives of the corridor stakeholders, including the users, will be realized through the coordinated efforts of the team. Travelers will realize maximum benefits through the central operation and collective management of VCTMC and experience a seamless transportation system offering choice and real-time information about corridor travel.

APPENDIX B

SYSTEM REQUIREMENTS SPECIFICATION SUMMARY

B.1 Requirements Framework

In formulating the system requirements for the I-15 ICMS system the project team always kept in mind the larger picture, that is, on the ICMS system itself. The team's objective is to produce a top quality system that truly stands out as a market leader and that is able to serve as a template for other regions interested in deploying ICMS systems to use as a model. To help satisfy this objective, the team developed a set of proposed requirements – in both content and quantity – for the I-15 ICMS System that is based on a two-part development strategy. The first part rests on the recommended guidance and practice from IEEE's specifications[1] documents and the second part focuses specifically on the San Diego region's vision for their ICMS system. The project team has as a result, a set of system requirements that is best suited for the San Diego region's unique combination of operating characteristics, transportation assets, and mobility management strategies. Upon reviewing this System Requirements document, the reader should have a complete appreciation of San Diego's ICMS system, including its description, context, subsystems, users and their roles, and constraints.

Additionally, readers will grasp the system requirements from static, dynamic and institutional perspectives. The static perspective provides system context. The dynamic perspective provides the reader with an understanding of how the ICMS system will operate under its Normal (short-term and long-term) Mode and Failure Mode (degraded operations, complete system failure and maintenance operations). In addition we have defined states through which the system transitions during Normal Mode operations. The institutional perspective provides an understanding of who the corridor stakeholders are and how they work as a management team.

The San Diego local area Stakeholder Working Group provided the technical and operational foundation for the document. The group conducted a series of workshops with both a "core" Working Group and an expanded team that included regional public safety personnel. This iterative process resulted in a set of detailed requirements reflecting the specific needs and systems of the San Diego Region. The Federal Technical Assistance Team[2] visited the site and provided further guidance on the development of both User Needs and System Requirements themselves. Through this process, the project team significantly and comprehensively updated our original set of User Needs to reflect the current and proposed ICMS system; and listed in an ordered way that reflects the flow of corridor activities during the lifecycle of the ICMS system.

In the second part of the requirements development strategy, the project team created a high-level functional decomposition modeled on our updated set of 17 User Needs, which provides the benefit of maintaining a one-to-one correspondence between the requirements within each functional area and its corresponding User Need. The team then partitioned the 17 functional areas two additional times according to (1) the current implementation state of the ICMS subsystems (operational or awaiting development and implementation) and (2) the context of the ICMS subsystems (internal or external to the ICMS).

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[1] *IEEE Guide for Developing System Requirements Specifications*, IEEE Std. 1233, The Institute of Electrical and Electronics Engineers, Inc., 1998 Edition; *IEEE Recommended Practice for Software Requirements Specifications*, IEEE Std. 830, The Institute of Electrical and Electronics Engineers, Inc., 1998 Edition.

[2] *Integrated Corridor Management – The Transition from a Concept of Operations to Requirements*, Mixon/Hill, Inc., Version 1.6, August 2007; Requirements Checklist for ATMS/ICMS Systems, Mixon/Hill, Inc., November 2007.

This approach has afforded the team an opportunity to take full advantage of the nature of the San Diego region's current and successful transportation management strategies. Moreover, the team has developed system requirements for the ICMS system in a systematic fashion that is detailed and complete. The project team is confident that this will also allow the San Diego region to move toward the system design phase in an efficient manner. This methodology provides SANDAG with the added benefit that the I-15 ICMS system should be readily transportable to other corridors within the San Diego region without major modifications. SANDAG fully intends to expand the ICM corridors beyond I-15.

Guided by this two-part strategy, the project team followed a detailed and iterative process that resulted in an extensive set of requirements in both depth and breadth. The process consisted of (1) repeated questioning as to whether each requirement describes a capability that the I-15 ICMS system must have to meet its objectives; whether it is well formed; and whether it refrains from designing the system; (2) revising requirements where necessary and (3) adding to the requirements list.

The project team views the development of system requirements as a dynamic and not a static process. While the team is confident that the current set of requirements covers all aspects of the proposed ICMS system for the I-15 Corridor, there will certainly be additional opportunities to again employ the described iterative requirements development process for further enhancements. Nonetheless, at this time, SANDAG and the region are fully prepared to move forward into the system design stage.

B.2 ICMS Requirements

The following 17 numbered paragraphs provide a high-level description of each of the 17 functional areas that comprise the requirements based on the Concept of Operations, various guidance documents provided by US DOT during the requirements development stage of Integrated Corridor Management and existing ICMS subsystem definition documents (Software Design Descriptions, System Requirements, System Architecture Descriptions, Interface Control Documents, etc.). Each of the below functions of the ICMS and its subsystems was derived from an expanded set of User Needs presented to US DOT on November 8, 2007 during the ICM Requirements Workshop. Each major function will contain all its associated requirement types, including constraints, data, functional, interface, hardware and performance. The I-15 project team feels that this approach will simplify the transition to the design phase of ICM by grouping all requirements related to a single function. For example, the designer for the *Data Collection and Processing* function will need to know what systems to interface to, what data elements are involved, what computer hardware is needed to store collected data and what functions are needed to collect and process the data.

Each requirement is coded with the following general schema: $XN.N_1.N_2.N_3.N_4. \ldots$, where X can be D (data), I (Interface), F (Functional), P (Performance), S (Security), or C (Constraint); N can take on numerical values ranging from 1 through 17 corresponding to each of the 17 functional areas/user needs of the same number; Subsequent classification levels indicated by decimal points and following numbers ($.N_1$, $.N_2$, $.N_3$, $.N_4$, etc.) indicate parent-child relationships among requirements.

1. ICMS Configuration Data Storage

ICMS Configuration data will be provided by a combination of existing modal databases and new configuration database tables containing I-15 corridor-specific information. Modal databases exist for ATMS 2005 (freeway), RTMS (MTS and NCTD transit) and RAMS (certain elements of arterials). Configuration data is needed, for example, for response plan processing, for data processing algorithms, to initialize certain ICMS functions and to track various static corridor metrics such as highway capacities and transit capacities. The data will be stored in a relational database instance and managed (created, modified, deleted) through a database management application. This application will be similar to the Browse-Edit application in ATMS 2005.

2. Data Collection and Processing

Data will be collected continuously from deployed modal management systems, including those listed below. Relative to the operational start date for the ICM demonstration, which is currently scheduled for the fall of 2010, the following dates apply (see Section 2.7.6, Table 2-5 for the complete list of scheduled deployment dates).

- ATMS 2005 (currently operational)
- Managed Lanes Control System (Middle Segment of I-15 Managed Lanes will be operational by January 2009)
- Lane Closure System (currently operational)
- Regional Transit Management System (currently operational)
- Regional Arterial Management System (fully operational by March 2009)
- Regional Event Management System (currently existing as California Highway Patrol)
- Congestion Pricing System (on Middle Segment of I-15 Managed Lanes will be operational by January 2009)
- Smart Parking System (initial deployment on I-5 scheduled for Summer 2008; framework for system regional extensibility completed by Spring 2010)
- Manual data from Regional Integrated Workstations (currently has completed acceptance testing; scheduled deployment in 2009)

Data processing is currently accomplished by IMTMS or the region's modal management systems. For example, IMTMS converts proprietary host data formats to standard XML schema using Agency Data Servers and ATMS 2005 computes travel times from designated CMS sign locations for up to two target destinations per sign. This data will be available to the ICMS system through the data collection function. However the ICMS system will require additional data processing to calculate metrics such as corridor capacity and excess corridor capacity in the aggregate and by mode, non-freeway travel times, etc. and to filter data according to a variety of parameters such as type and source.

3. ICMS Historical Data Storage

Data collected by ICMS and IMTMS subsystems is generally held in legacy databases for various uses. For example, the ATMS 2005 system maintains an instance of an Oracle database for historical archiving. This Oracle instance stores real-time data every data cycle and executes database routines to aggregate the real-time data into longer time periods.

Online data is stored for approximately 13 months for reporting purposes. A Reports function uses the Historical database and various pre-stored database procedures to display traffic congestion, operational events and system failures across user-selectable time periods. Likewise, the RTMS transit application stores real-time bus location, schedule adherence and event data to produce ad-hoc reports using a third-party report-creation application.

The QuicNet 4 traffic signal control system maintains a reporting function for real-time and historical intersection data, including alarms, events (timing plan changes, emergency preemption) and traffic count data. The California Performance Monitoring System (PeMS) currently collects real-time data from all Caltrans districts in the state and makes a variety of configurable reports available by district and by highway.

For I-15 Corridor purposes, this data must be shaped and tailored to the I-15 Corridor boundaries. The ICMS will have the capability to access these reporting mechanisms as an external client. *ICMS will not maintain a separate historical database for existing corridor modal data*. However ICMS will maintain a historical database for corridor-wide data or for modal data specific to corridor operations.

4. Information Publishing (Corridor Managers)

Processed data will be available to all participating agencies through a regional data distribution mechanism. Participating agencies will include traffic, transit, public safety and emergency management. Data will be shared using HTML and XML data formats. HTML data will be viewable through standard PC-based browsers such as Internet Explorer and Mozilla Firefox. XML data will be provided for third-party applications. An XML data schema will be maintained along with XML data integration guidelines for potential application developers. In addition, information publishing will support agency personnel notification systems such as pagers, e-mail, Fax, text messaging and instant messaging. In this manner information publishing to corridor managers differs from information publishing to corridor users where personalized alerts and travel information are provided as revenue services by the regional 511 Information Service Provider.

5. Multi-Agency Collaboration

Multi-agency Collaboration will provide corridor agencies with the means to share voice, video, imagery and data collaboratively, both for routine management and for the management of major events (planned or unplanned). Multi-agency conferencing will support the concept of a virtual Corridor TMC by allowing decision makers to share data and pool their knowledge from different physical sites. This function can be supported by systems such as the San Diego region's Command, Control & Communications (3C's) high-bandwidth microwave network and commercial off-the shelf collaborative communications tools.

6. Information Display

Information produced by ICMS and its subsystems will be displayable on workstations, large screen displays and handheld devices. Corridor information is displayed and managed through user dialogues on a browser-based workstation, an upgrade to the existing Regional Integrated Workstation (RIWS). A regional map will be manipulated by the operator for scale, management of display layers, panning, and assignment of information to a large screen display and selection of dynamic icons for viewing of field device data.

7. Transportation and Public Safety Event Management

Based on the receipt of non-recurring incident information from all sources (Mobile 911, callbox, CCTV, road crews, Traffic Officers, etc.), ICMS will provide the capability to manage the complete life-cycle of an event across multiple agencies. This includes the ability to create and terminate events by agency, to split one event into multiple events, to merge multiple events into one event and to transfer an event from one agency to another. "Transfer" in this context means to transfer responsibility for event management. Event Management differs from the REMS Subsystem of IMTMS in that the REMS Subsystem collects the data via defined interfaces while Event Management provides functionality to manage event lifecycles.

8. Shared Device Control

Less complex but still needing regional agreements are the shared control of CMS signs and Highway Advisory Radios (HAR). CMS functionality includes prioritization of messages, message scheduling and message library management – shared use will take these features into account.

9. Video Management

Arguably the most complex, and yet useful sensor system in the region is the multi-agency collection of video surveillance systems. The largest systems are owned by Caltrans for freeway monitoring and event confirmation and by MTS/NCTD for station and parking security. ICMS will provide the capability for users to select cameras from a graphical user interface and subject to regional agreements, to control selected operations of these cameras, such as pan, tilt, zoom, focus, iris control, etc. ICMS will support a video wall management capability for future dedicated facilities. Video display formats will include live streaming video, archived video clips and video snapshots.

10. Response Plan

ICMS will determine the appropriate response for managing traffic in response to major perturbations in "normal" traffic due to traffic incidents, special events, emergency closures, construction and/or major disasters. The heart of the DSS subsystem within ICMS is the ability to analyze collected data, ascertain abnormal or scheduled events, determine appropriate responses and suggest a set of actions that collectively form a "response plan". The response plan may be manually or automatically generated, but if automatically generated, will include the capability for human operator review and modification. This is particularly critical for field device (i.e. CMS sign and camera) control actions.

11. Impact Assessment

ICMS will use a micro/meso scale modeling tool to assess the impact of both short-term responses to planned and unplanned events in the Corridor (such as the recent wildfires in San Diego) and long-term strategies to optimize corridor performance based on cumulative measures of corridor performance.

12. Information Publishing (Corridor Users)

Processed data will be made continuously available to the Regional 511 program for public dissemination. This includes freeway, arterial and transit incidents, congestion data, travel times, ramp meter status and any future data types such as parking availability, congestion pricing, etc. The 511 system will be responsible for selecting and activating all appropriate means of delivery including www, e-mail, pagers, wireless devices and landline telephones.

13. Corridor Performance Measurement

Corridor performance is characterized by freeway, HOV and arterial metrics, transit route performance (on-time, average speed, ridership), smart parking usage, the impact of congestion pricing algorithms, ramp metering, etc. The level of detail of data collected will be sufficient to support corridor management strategies for demand and capacity management.

In this section we focus on performance measures encompassing the following four major categories: Mobility, Reliability, Productivity, and Safety. Examples of specific performance measures include:

- Traffic volumes
- Speeds
- Level of service
- Travel time
- Vehicle/people miles traveled
- Vehicle/people hours traveled
- Vehicle hours of delay
- Transit productivity
- Transit reliability
- Travel time
- Number of incidents
- Incident rate
- Number of injuries and fatalities
- Injury and fatality rates

14. Capacity and Demand Management

Long term corridor management is needed to optimize traveler throughput and other metrics established by regional policy. This entails measuring highway, transit, parking and congestion pricing performance over an extended period and applying this data to various capacity and demand management strategies. Demand management in the corridor includes van pooling, smart parking, congestion pricing while capacity management includes managed lanes, ramp metering, traffic signal synchronization, transit service changes and transit signal priority. The effect of these strategies is then measured through the following requirements.

15. System Performance Measurement

System performance measurement encompasses the collection of data related to system failures, bandwidth allocation, server reliability and availability, communication link performance and other metrics related to the management of ICMS subsystems.

16. System Management

ICMS will implement a security system that allows the shared viewing of regional resources and the shared control of selected field devices. Shared viewing and control will be subject to regional agreements to be determined. System security will as a minimum implement user privilege levels and a password system linked to user levels. ICMS will provide the capability to add new users, delete users and modify user privileges. System management will also include the ability to backup critical files on an automatic schedule and to archive data to off-line storage for retention purposes.

17. Life Cycle Management

Software will form an integral part of the Integrated Corridor Management System. There is a proliferation of standards, procedures, methods, tools, and environments for developing and managing software. This proliferation has created difficulties in software management and engineering, especially in integrating products and services. ICMS will use an industry-standard framework that can be used by ICMS developers, managers, operators, maintainers and trainers to "speak the same language" to create and manage the software component of ICMS. The IEEE/EIA 12207.0-1996 Standard for Life Cycle Processes will provide such a framework for ICMS and guide its use throughout the ICMS life cycle.

The framework covers the life cycle of software from conceptualization of ideas through retirement and consists of processes for acquiring and supplying software products and services. In addition, the framework provides for controlling and improving these processes. The processes in this IEEE Standard form a comprehensive set. The Standard is, therefore, designed to be tailored for an individual project, in this case ICMS. It is designed to be used when software is an embedded or integral part of the total system, such as is the case with ICMS.

APPENDIX C

SAMPLE DATA LIST FOR ANALYSIS, MODELING AND SIMULATION

C.1 Introduction

The following FTP site has been set up for the purpose of transferring transportation model data for San Diego's ICM concept of operations:

ftp://ftpx.sandag.cog.ca.us/pub/ICM_AMS/

SANDAG has been providing economic and demographic forecasts for more than 30 years, and transportation forecasts for more than two decades. SANDAG strives to stay in the forefront of forecasting technology. It uses "best practices" methodology adapted to local conditions. To ensure that this continues, SANDAG subjects its forecasting efforts to peer review by other forecasting professionals in the region. In addition, the forecasting methodology used by SANDAG is presented at national, regional, and local meetings of professional demographers, economists, and land use and transportation planners.

SANDAG uses four models in our forecasts: (1) the Demographic and Economic Forecasting Model (DEFM), (2) the Interregional Commuting Model (IRCM), (3) the Urban Development Model (UDM) and (4) the Transportation Forecasting Model (TransCAD). All of the models used at SANDAG incorporate "best practices" used by Metropolitan Planning Organizations (MPOs) and councils of governments throughout the nation. In addition, SANDAG is continually evaluating and refining its models and incorporating updated techniques and information as necessary.

After preparing model inputs, there are four major steps of trip generation, trip distribution, mode choice, and assignment, along with a minor function of path-building and skimming. One of the complexities of the modeling process is that transportation measures needed as input to a modeling step may not be produced until later in the modeling process. For this reason there are numerous iterations through the modeling process. As a starting point, the first-stage of the modeling process makes use of simplified trip distribution, mode choice, and highway assignment procedures to produce initial highway travel time forecasts for use in the subsequent feedback loop phase.

To save processing time, the trip distribution model is performed on a trip distribution zone (TDZ) system with only 2000 zones while the rest of the steps are performed on the traffic analysis zone (TAZ) system with 4605 zones. SANDAG uses a nested mode choice mode that splits total person trips into 25 different sub-modes. The model computes mode use separately for two time periods, three income levels, and six trip purposes. Fixed and variable tolls are included to allow modeling for High Occupancy Vehicle (HOV) lanes, High Occupancy Toll (HOT) or Managed Lanes, and for fixed toll roads.

Complete documentation for all of the above mentioned models is available on SANDAG's web site:

http://www.sandag.org/uploads/publicationid/publicationid_833_3750.pdf

C.2 Sample Data List

C. 2.1 Available Models at SANDAG

- **Available Models**
  - The Series 11 growth forecast is the latest socio-economic data used in SANDAG's transportation model. It has a base year of 2003, a horizon year of 2030, and has the ability to perform phased model alternatives in five year increments.

  - SANDAG's model is assumed to be an 'average weekday' model and does not attempt to model special events and/or weekends.

  - SANDAG uses **TransCAD version 4.8** and Arc Info version 9.2 for traditional four-step modeling throughout the region.

  - SANDAG has **CUBE Dynasim version 1.4** for traffic micro-simulation modeling. Use of traffic micro-simulation models at SANDAG is minimal at best. Dynasim has been evaluated by SANDAG and Caltrans District 11 staff. For a full report and traffic simulation demo files, Mike Calandra should be contacted (See below for contact information).

  - SANDAG will obtain a version of **TransMODELER version 1.5** in the near future.

- **Studies Completed**

  - The I-15 Managed Lanes project has been studied for several years under the previous growth forecast (Series 10), and split into three subsections. The first of the three subsections is currently under construction with a targeted completion of 2010, with the remaining two subsections slated for construction to commence in 2012. Multiple transportation model alternatives were run to support Managed Lanes operations, access points and direct access ramp (DAR) locations.

  - For reports on the I-15 Managed Lanes project, Mike Calandra should be contacted (See below for contact information).

  - **AMS Point of Contact**
    - Mike Calandra will be running the 4-step model for this project and Tom King will be providing transit route, demand and ridership information.

  - **Points of Contact**
    - Mike Calandra is the main modeling contact for SANDAG (619-699-6929 / mca@sandag.org).

    - Tom King is the transit modeling contact for SANDAG (619-699-6962 / tki@sandag.org).
    - Maurice Eaton is the modeling contact for Caltrans (619-688-3137 / maurice_eaton@dot.ca.gov).

    - Conan Chung is the contact for MTS, however all modeling for MTS is provided by SANDAG.

- Stephan Marks is the contact for NCTD, however all modeling for NCTD is provided by SANDAG.

- **Internal Capabilities**

  - SANDAG's transportation planning model is used primarily to develop the Regional Transportation Plan (RTP), and for project development and corridor studies with partners such as Caltrans.

  - Via SANDAG's Service Bureau, the planning model is also used by local jurisdictions for Circulation Element updates, and by developers and consultants for private land use development impacts on the transportation system.

  - The planning model is easily converted to a region-wide subarea model with the ability to subdivide and/or aggregate TAZs, add and/or delete network elements, and override regional land use inputs with development-specific land use inputs.

  - The travel demand model can be used to produce microscopic traffic simulation trip tables and networks, however it is not recommended to attempt a microscopic traffic simulation model based on long-range travel demand data.

- **Commitment to Performance Measurement**

  - Freeways: Caltrans' traffic census and the PeMS web site are the primary sources of performance measurement:

    http://pems.eecs.berkeley.edu/

  - Arterials: SANDAG does not collect traffic data for arterials in any of the 19 jurisdictions within San Diego County. SANDAG does however gather the traffic count data from the local jurisdictions, and publishes them here:

    http://www.sandag.cog.ca.us/resources/demographics_and_other_data/transportation/adtv/index.asp

  - Alex Estrella is the main traffic count data contact for SANDAG (619-699-1928 / aes@sandag.org).

C. 2.2 Input Data for AMS

- **Network Data**

  - Since 1986, SANDAG has been 100% committed to the GIS package Arc/INFO for socio-economic forecasts, land use tracking and transportation modeling.

  - A Master transportation coverage (TCOV) has evolved over 20 years and is a link/node based line layer with arc attributes, node attributes and two critical Dynamic Segmentation tables for transit routes and turn prohibitors. TCOV is comprised of all Circulation Element roads in San Diego County, plus some local links for connectivity. Project codes are used to pull from TCOV appropriate highway networks for transportation model alternatives.

- A “Base Year 2003” network has been converted to an E00 file on a SANDAG FTP site. The layer is named *hwy03.e00* and the meta-data Word Document *hwycovfields.doc* should be used with the layer.

- **Travel Demand 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/

  - Base year 2003 O-D trip tables for both ‘Person’ and ‘Vehicle’ trips are available through the FTP site. There are 10 person trip tables – one for each trip purpose, and 3 vehicle trip tables - one for each of the 3 time periods (AM = 6am – 9am, PM = 3pm – 6pm, Off Peak = the remaining 18 hours of the day). The tables provided are in TransCAD format and have been compressed into one zip file called *odtables.zip*:

  - Arterial count data at a level finer than ADT is not available at this time. There are no surveillance systems for arterials in place in the San Diego region. Peak hour direction volumes can be obtained from the *hwy03.e00* layer as a model output.

  - A traffic analysis zone layer is available on the FTP site. The file name is *zones.e00* and the key field on the polygon attribute table is ‘zone’.

  - A study area map is available on a SANDAG FTP site. The file name is *sd_icm_2004.pdf* and it includes the proposed study area, the existing 2004 street network, 2004 transit stations, and the phasing of the under-construction managed lanes.

  - A study area GIS layer is available on a SANDAG FTP site. The file name is *sacov.e00*. This layer was used on the study area map from the bullet above.

- **Travel Surveys**
  - A region-wide travel behavior survey was conducted in 1995:

    http://www.sandag.org/uploads/rfpid/rfpid_97_4459.pdf

  - A region-wide travel behavior survey was conducted in late 2006 and a new data set and report is due to SANDAG in mid-2007.

  - Caltrans produced a statewide travel survey in 2001:

    http://www.dot.ca.gov/hq/tsip/tab/travelsurvey.html

- **Traffic Control Data**
  - Traffic controls are stored as node attributes in SANDAG’s GIS-based network application. The data includes the type of control (i.e. signal, all-way stop, two-way stop, ramp meter, and toll booth and rail crossings) and the proposed installation of the control (what year the control might come on line). SANDAG does not have any traffic signal timings, phasing or coordination plans, this information would have to come from the local agencies and Caltrans.

- A list of all intersections and their control types within the proposed ICM study area can be found in the spread sheet *tcd03.xls* on a SANDAG FTP site.

- Traffic signal times and phases from the Quick Net 4 system from the cities of San Diego, Poway and Escondido will be provided.

- The file *ct_ams.zip* contains sample signal timings, ramp meter rates, CAD logs, loop detector status and other sample data sets from Caltrans.

- **Transit Data**
    - Transit ridership data is available through surveys and on-board passenger counting programs. Transit routes and stops are coded in a GIS-based network application and can be edited for route configuration tests.

    - A "Base Year 2003" transit network has been converted to an E00 file and placed on a SANDAG FTP site. The layer is named *trcov03.e00* and the meta-data Word Document *trcovfields.doc* should be used with the layer:

    - A text file called *headways* is available on a SANDAG FTP site, and contains bus route configurations and frequencies used in the modeling process to satisfy FHWA mode choice requirements.

- **Map Data**
    - A study area map is provided on the FTP site. The file is named *sd_icm_2004.pdf* and includes the study area and construction phases of the Managed Lanes, plus street, intersection and transit information.

    - An existing level of service map has been placed on the FTP site. The file is named *sd_icm_2004los.pdf* and includes the worst-case level of service experienced by direction for each link in the system.

    - An existing capacity map is on the FTP site. The file is named *sd_icm_2004cap.pdf* and shows existing roadway capacities via bandwidths.

    - A future capacity map is also available on the FTP site. The file is named *sd_icm_2030cap.pdf* and shows the capacity of the roadways after completion of the Managed Lanes.

    - A sample aerial image has been placed on the FTP site. The file is named *sd_icm_int.pdf* and is focused on the Pomerado Rd / Twin Peaks Rd intersection to match the sample intersection data from the City of Poway.

- **ITS Elements**
    - Both fixed and variable tolls are used to calculate travel times in the model. The existing I-15 HOV lane uses the FastTrak electronic toll collection system to asses varying tolls on the facility.

    - There is no mechanism for re-routing traffic based on en-route or pre-trip travel time information.

- SANDAG's model is an average weekday demand model, thus it is not used for incident management or major events.

- Automatic location systems and passenger counting programs are in place. The counting program is used to calibrate the base year mode choice model however the location system is not used in the modeling process.

- Incidents, like events, are not included in the modeling process. Freeway incident data can be procured from either the Freeway Service Patrol, or Caltrans' TASAS data base.

- The trip generation model includes the ability to reduce certain work trips (i.e. Office and commercial) a small percentage to accommodate telecommuting and e-commerce.

2.3 Performance Data for Model Calibration and Validation

SANDAG's travel demand model was designed to compute transportation system impacts such as traffic volumes, traffic speeds, and transit ridership for transportation network and policy alternatives given land use and demographic forecasts from the IRCM, UDM, and DEFM. SANDAG makes use of an advanced four-step transportation modeling process of trip generation, trip distribution, mode choice, and assignment to forecast travel activity in the San Diego region.

SANDAG's travel demand model is a planning model and not an operational model. Traffic simulation models can be used as an operational model so long as the study area is defined as a small geographic area, and so long as the area being simulated is based on observed data and not on planning model data.

Before running the models in production, a considerable amount of time is spent calibrating model parameters and validating model accuracy. The purpose of calibration is to develop model relationships that can accurately reflect existing travel behavior, so there is confidence the models can be used to forecast future travel behavior. For example, the models correctly estimate current trolley ridership so they should be able to forecast future ridership on proposed trolley extensions and on new bus rapid transit service. Most recently the models were re-calibrated to year 2003 conditions before use in the 2030 RTP.

Due to extremely tight RTP deadlines, SANDAG's regional model is calibrated at the freeway level. The regional model undergoes more scrutiny during corridor studies and Service Bureau production jobs where all links within a defined study area are calibrated.

- **Calibration for Capacity**
  - Freeways: Capacity data is collected link-by-link from PeMS for the entire freeway system and coded into the master transportation coverage (TCOV). Thus actual real world capacities are used in SANDAG's planning model. A majority of San Diego's freeway system is 50+ years old, thus the observed per-lane per-hour capacities are quite low when compared to HCM standards. Modeled capacities can be found in the GIS network layer ***hwy03.e00***.

  - Arterials:
    - Mid-Link: Mid-link capacities for urban street segments are calculated using the equation below. Two-lane rural highways typically can accommodate much less traffic and a lower capacity of 950 vehicles per hour per direction is assumed for these facilities.

$$urbc = ln \times 1800 - 300 - 200(m < 2)$$

Where:
urbc = urban street mid-link capacity for link
ln = number of mid-block lanes on link
m = median code (0 or 1 indicates no median)

- Intersection Approach Capacity: Because the most significant traffic congestion on urban streets often occurs at traffic signals, procedures have been developed to represent individual signal approach capacity within the model using the following equation.

  $xc = (tl \times 1800 \times gc(fc,xfc,napp) + (rl + ll) \times tlc(fc)) \times 1.0 \rightarrow 1.1$

  where:
  xc = intersection approach capacity for link
  tl = number of through lanes at intersection approach
  gc = green-to-cycle time ratio
  fc = functional classification of street
  xfc = functional classification of cross street
  napp = number of intersection approaches
  rl = number of right turn lanes at intersection approach
  ll = number of left turn lanes at intersection approach
  tlc = per lane turn lane capacity that varies by functional classification

While actual signalized operation is very complex, this equation captures the primary factors that determine capacity. A through lane capacity of 1,800 is multiplied by the number of approach lanes that have been coded. The green-to-cycle time (*gc*) ratio is a traffic engineering term that quantifies the fraction of total cycle time that is in the green phase for each intersection approach. Within the model, *gc* ratios vary between 0.09 and 0.84 depending on the functional classification of intersecting streets and number of approaches. For example, a prime arterial that intersects with another prime arterial would have a lower capacity than one with the same approach lane configuration that intersects with a local street. Similarly, two and three legged intersections have higher capacities than four legged intersections because total cycle time is apportioned to fewer phases.

A turn lane capacity that varies between 100 and 250 vehicles per lane per hour depending on the functional classification of the street is multiplied by the number of coded right and left turn lanes and added to through lane capacity. Finally, future capacity increases of up to 10 percent are phased in on regionally significant arterials as a result of improved signal coordination assumed in the 2030 RTP.

- **Route Choice Calibration**
    - Screen Line Analysis is performed on all links in the highway network as well as on all routes in the transit network. Screen lines are defined by identifying isolated network accessibility as well as many other geographic factors.

    - Post forecast volume adjustments are performed on all links that were in the base year 2003 network that had valid traffic counts on them. The difference between the base year assigned volumes vs. the base year ground count is the basis for all volume adjustments. The *hwy03.e00* file contains two fields related to this process: 'uvol' contains the raw model daily traffic volumes while 'avol' contains the adjusted daily traffic volumes.

- **System Performance Calibration**
    - Capacities can be found on the *hwy03.e00* GIS layer.

    - Daily raw and adjusted volumes can be found on the *hwy03.e00* GIS layer, as can peak hour directional volumes for both the AM and PM peaks.

    - Modeled travel times can be found on the *hwy03.e00* GIS layer for the peak hours (congested) as well as the off peak period (free flow).

    - SANDAG's travel demand model is a planning model and not an operational model, thus it is not possible to collect neither spatial nor temporal queue lengths.

Input and Output Data Availability from SANDAG's Travel Demand Model

NETWORK	TRAVEL DEMAND	TRAFFIC CONTROL	TRANSIT	ITS ELEMENTS
Link Distances	**Link Volumes**	**FREEWAYS**	**Transit Routes**	***Surveillance System***
Free-Flow Speeds	**Traffic Composition**	**Ramp Metering**	**Transit Stops**	***detector type***
Geometrics-FREEWAYS	**On & 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/strategies	**Transit Schedules**	***CMS***
operation of HOV lanes	**Transit Ridership**	**Mainline Control**	schedule adherence	***HAR***
accel/decel 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***	***Paratransit***	***CAD system***
# lanes		***controller type***	***demand-responsive***	***response & clearance***
lane usage		***phasing***	***ride-share programs***	**Tolling System**
length of turn pockets		***detector type & placement***		type
grade		***signal settings***		pricing mechanisms
turning restrictions		***Signal Timing Plans***		***TMC***
on-street parking		***Transit Signal Priority***		***control software/functions***
Parking Facilities		***control logic***		***communications***
location		***detection***		***data archival/dissemination***
capacity		***settings***		***Transit Management System***
Park & Ride Lots		***Emergency Preemption***		***AVL***
location		***control logic***		***communications***
capacity		***detection***		***travel information at bus stops***
		settings		

xxx: data readily available from SANDAG
xxx: data provided by partner agencies
xxx: data can be obtained from as-built plans/aerial photos
xxx: additional analysis required