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INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Connected Corridors: I-210 Pilot Integrated Corridor Management System

Concept of Operations

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EXECUTIVE SUMMARY

This document presents the Concept of Operations ("ConOps") for a pilot Integrated Corridor Management (ICM) system proposed for deployment along a section of the I-210 corridor in the San Gabriel Valley sub-region of Los Angeles County. This corridor, illustrated in Figure E-1, includes the I-210 from the Arroyo Boulevard interchange in Pasadena (Exit 22B) to the I-605 interchange in Duarte (Exit 36), sections of the SR-134 and I-605 freeways, several key surrounding arterials, and several transit systems serving the corridor.

The ConOps presents the cross-jurisdictional travel management strategies that are being considered by the various stakeholders to improve overall corridor operations during significant incidents and events. It is a document specifically written from the perspective of the corridor stakeholders to foster agreement on an overall approach, an organizational structure, and relevant processes. Upon successful concurrence with the corridor stakeholders, the system launch is currently projected to occur in 2017.

Figure E-1 – I-210 Pilot ICM Corridor

BACKGROUND

This project, referred to as the "I-210 Pilot" is part of a larger vision called "Connected Corridors," a collaborative effort led by the California Department of Transportation (Caltrans) to research, develop, and test a framework for transportation system management on multiple corridors in California. The Connected Corridors vision and the I-210 Pilot look at an entire transportation network and all opportunities to move people and goods in the most efficient and safest manner possible.

RELATED FUNDING AND ORGANIZATIONAL CHANGES

Over $30 Million has been identified to fund initiation of the I-210 Pilot. Funding has also been provided in the governor's new budget for the creation of permanent positions within Caltrans tasked with leading the collaborative corridor management process and enabling performance based management. These organizational changes are already well underway with the hiring of new personnel and the creation of a new corridor management organization at Caltrans. Additional funds are being requested from federal, state, regional and local sources through multi-agency applications supported by all corridor stakeholders.

SYSTEM STAKEHOLDERS

Stakeholders in the I-210 Pilot include agencies and groups having a direct interest in system operations and in how the system affects travel conditions in the corridor. Participation by and coordination among the stakeholders is vital to the project's success. The key system stakeholders are:

- ✓ California Highway Patrol (CHP)
- ✓ Caltrans District 7 and Headquarters
- ✓ City of Arcadia
- ✓ City of Duarte
- ✓ City of Monrovia
- ✓ City of Pasadena
- ✓ Foothill Transit,
- ✓ Los Angeles County Service Authority for Freeway Emergencies (LA SAFE)
- ✓ Los Angeles County Department of Public Works (LADPW)
- ✓ Los Angeles County Metropolitan Transportation Authority (Metro)
- ✓ Metro Bus and Metro Rail,
- ✓ Pasadena Area Rapid Transit System (ARTS)
- ✓ Southern California Association of Governments (SCAG)
- ✓ San Gabriel Valley Council of Governments (SGVCOG)
- ✓ University of California, Berkeley – PATH
- ✓ US Department of Transportation (USDOT)

To date, multiple meetings have been held with the stakeholders, including introductory meetings, technical briefings, City Council presentations, and user needs workshops. Meetings and outreach (using various tools and strategies) will be ongoing throughout the project.

DOCUMENT CONTENT

The development and approval of a ConOps is an important step in the Systems Engineering process, and a key component leading to the development of system requirements and the design of a proposed system. The ConOps describes technologies, systems, and operational concepts that could be used to better control and manage the freeway, arterial and transit networks of the I-210 corridor. It builds on the experiences of other ICM projects in the United States, such as the I-15 ICM in San Diego, US-75 ICM in Dallas, and I-80 ICM in the San Francisco Bay Area.

The focus of the ConOps is on improving overall operations within the I-210 corridor, developing real-time corridor evaluation tools, and enabling performance-based management practices. It first outlines the scope of the I-210 Pilot project and the key reference documents that were used to develop it. An overview of the I-210 corridor follows. It describes the jurisdictional environment, surrounding land uses, existing roadway and transit systems, and existing transportation management assets, such as traffic management centers (TMCs), traffic signal systems, ramp meters, park-and-ride facilities, and traveler information systems. This is further complemented by a characterization of travel patterns, congested areas, travel reliability, and safety hotspots.

All of these elements lead to the justification for the project and the outlining of its vision, goals, and objectives, along with a description of the proposed ICM system concept and the identification of involved stakeholders. The user needs that were collaboratively developed with the corridor stakeholders are then presented and utilized to define suggested management strategies, organizational structures and the system architecture. Based on the defined system framework, conceptual operational scenarios are then described for review, followed by a summary of anticipated system impacts and benefits.

OPERATIONAL APPROACH

The I-210 Pilot aims to develop strategies for the coordinated management of the I-210 freeway, surrounding arterials, transit, and other relevant transportation systems to improve overall mobility and safety within the corridor. The primary focus is on managing travel conditions during incidents and events having a significant impact on travel.

To achieve these goals and objectives, a number of corridor improvement strategies are being considered. The basic operational approach is to:

1) Identify the location and severity of significant incidents occurring on the corridor
2) Estimate the near-future impacts of the incident on corridor operations
3) Assess what corridor elements can be used to implement a response to the incident
4) Determine the best alternate traffic route(s) around the incident based on available assets
5) Modify ramp metering rates and traffic signal timings at intersections to facilitate travel along the identified alternate route(s)
6) Utilize various technologies to provide relevant information to travelers and stakeholders
7) If the incident is sufficiently severe, engage with transit and additional stakeholders to expand the possible management response

Further operational gains are sought through the following elements:

- Enhancements in traffic and travel monitoring capabilities
- Expansion of data communications across agencies
- Deployment of corridor operational evaluation tools suitable for real-time operations, including a decision support system to help system operators with traffic management decisions
- Cross-jurisdictional coordination

ANTICIPATED BENEFITS

The following are the expected I-210 Pilot benefits:

- Improvements in travel time reliability and delay
- Reduced incident response times, including response to the incidents themselves and the implementation of travel mitigation plans
- Likely reductions in secondary incidents, leading to improvements in safety

- Enhanced coordination between Caltrans, local traffic management agencies, transit agencies, first responders, and traffic management centers
- Increased attractiveness of transit services
- Improved traveler experience
- New decision-making tools to improve corridor operations for the freeway and arterials

KEY PERFORMANCE MEASURES

Key performance measures for the following areas will be developed and tracked for the I-210 Pilot:

- Mobility: Better people and freight movement
- Reliability: More predictable corridor travel times
- Safety: Fewer collisions, injuries, and fatalities; and less severity
- Productivity: Fewer bottlenecks or hotspots that reduce flow rates
- Emissions and Fuel Consumption: Reduced greenhouse gas emissions

GUIDE FOR MORE DETAILED INFORMATION

While all sections of the ConOps present valuable information, interested readers may consult the following key sections for more in-depth information about the proposed I-210 Pilot system:

- **Section 2 – Project Scope**
- **Section 7 – Justification for Change**
    - 7.3 – *Desired Changes*
- **Section 8 – Proposed System Concept**
    - 8.2 – *Goals and Objectives*
    - 8.6 – *Potential Operational Framework*
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- **Section 14 – Operational Scenarios**
- **Section 15 – Summary of Impacts**

1. PURPOSE OF DOCUMENT AND SUMMARY

This Concept of Operations (ConOps) presents a vision for the development and implementation of an Integrated Corridor Management (ICM) system along a section of the I-210 corridor in the San Gabriel Valley sub-region of Los Angeles County. This vision was developed for a project led by Caltrans District 7 with assistance from Caltrans Headquarters, the Los Angeles County Metropolitan Transportation Authority (Metro), the Los Angeles County Department of Public Works (LACDPW), and the Partners for Advanced Transportation Technology (PATH) at the University of California, Berkeley. Additional key participants include the cities of Pasadena, Arcadia, Monrovia, and Duarte; the California Highway Patrol (CHP); the Los Angeles County Service Authority for Freeway Emergencies (LA Safe); Foothill Transit; Pasadena Transit; the Southern California Association of Governments (SCAG); and the San Gabriel Valley Council of Governments (SGVCOG).

The vision describes how emerging technologies and operational concepts could be leveraged to enhance the control and management of a transportation corridor comprised of a freeway, several arterials, and various transit systems. It is in part built upon the experiences from other recent efforts to implement ICM systems within the United States, such as the USDOT-sponsored demonstration projects along the I-15 corridor in San Diego and the US-75 freeway in Dallas, as well as the I-80 ICM project sponsored by the Alameda County Transportation Commission in the San Francisco Bay Area. The ConOps is further based on the premise that significant progress in demonstrating the viability of ICM concepts have been made in previous demonstrations and that the viability of the concept thus need not to be proven anymore. Its focus is on improving overall I-210 corridor operations. This is sought by enhancing system awareness and real-time operational management capabilities; developing new corridor evaluation tools suitable for use in real-time operational settings; and eventually, and providing novel ways of influencing travel demand by attempting to leverage emerging wireless communication capabilities among vehicles, infrastructure, and travelers.

Elements described in the remaining parts of this section include:

- Brief overview of the project
- Relation of document to the systems engineering process
- Specific questions to be addressed
- Content of document
- Suggestion for expedited reading

1.1. PROJECT OVERVIEW

The I-210 ICM Pilot projects aims to develop strategies for the coordinated management of the I-210 freeway, surrounding arterials, and other relevant transportation systems to improve overall mobility within the corridor. At this stage, the focus is on managing travel conditions during incidents and events having a significant impact on travel activities. Operational improvements are sought through the coordinated operation, where feasible, of:

- Freeway on-ramp meters
- Freeway-to-freeway connector meters
- Arterial traffic signal control systems
- Transit systems

- Parking systems
- Traveler information systems

Operational gains are further sought through the following elements:

- Enhancements in traffic and travel monitoring capabilities
- Expansion of data communication capabilities across agencies
- Deployment of corridor operational evaluation tools suitable for real-time operations
- Cross-jurisdictional cooperation

1.2. RELATION OF DOCUMENT TO SYSTEMS ENGINEERING PROCESS

The development of the ConOps is part of the systems engineering analysis process that the Federal Highway Administration (FHWA) requires be followed for the development of Intelligent Transportation System (ITS) projects. Figure 1-1 illustrates the typical steps associated with the process. As the figure shows, the development of a ConOps typically occurs after a needs assessment and some preliminary project planning have been conducted; but before a full design is initiated. In this context, as illustrated by the contextual diagram in Figure 1-2, the primary functions of a ConOps are to:

- Establish the rationale for the system;
- Refine the vision, goals, and objectives of the proposed system;
- Develop representative operational scenarios illustrating what the proposed system will do;
- Ensure that the needs and expectations of stakeholders are captured early in the system development process;

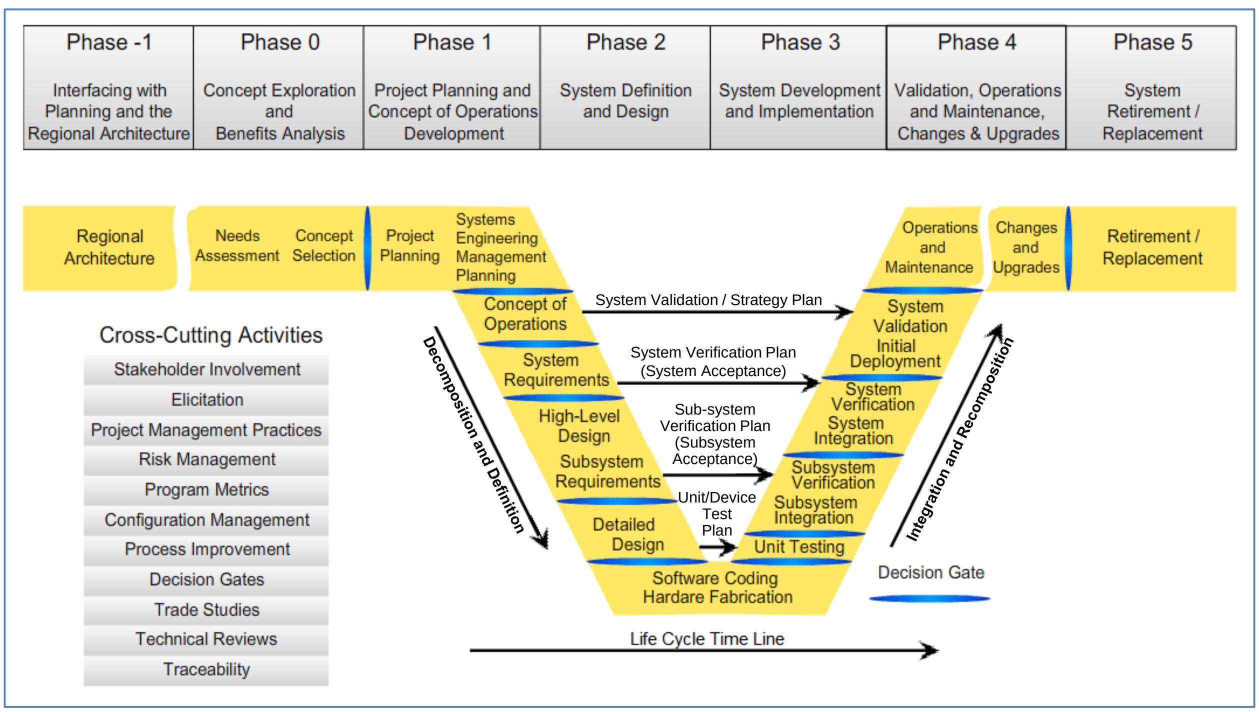

Figure 1-1 – Systems Engineering Process ("V" Diagram)

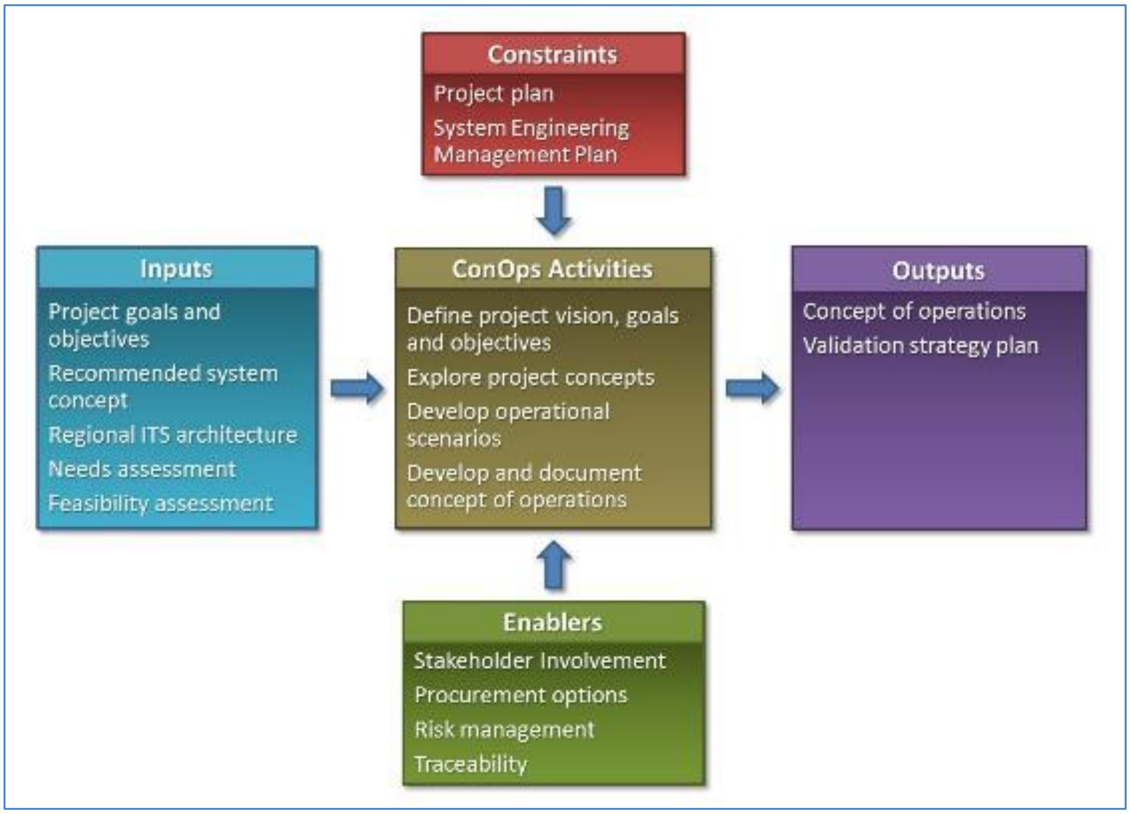

Figure 1-2 – Context of ConOps

- Ensure that the system functionalities are linked to the mission, goals, and objectives of participating agencies; and
- Begin the traceability of the Systems Engineering Process.

A ConOps seeks more specifically to illustrate the benefits that can be obtained from the application of advanced technologies; the coordination of systems traditionally used independently to manage the movements of vehicles, persons, and goods within a corridor; and the development of cooperative operations among corridor systems and stakeholders. Only high-level descriptions are typically provided in a ConOps as this document is primarily meant to act as a discussion vehicle and consensus-building tool among potential project stakeholders.

1.3. SPECIFIC QUESTIONS TO BE ADDRESSED

Specific questions that the ConOps seeks to address regarding the proposed I-210 ICM system include:

- What are the goals and objectives of the system?
- How will the system achieve its stated goals?
- How can corridor performance be adequately captured?
- How will existing corridor operations be enhanced by the proposed system?
- What new functionalities will be provided by the system?
- Who are the system users?
- Who are the various system stakeholders?
- What are the stakeholders' specific roles?

- What are the operational and institutional environments in which the system will operate?
- What would be the main system components and functionalities?
- What sequences of activities will typically be performed to address specific situations or requests of interest?
- What resources would be needed to design, build, operate, and maintain the system?
- What operational, technical, and institutional elements may influence the design and implementation of an actual system?

While it is expected that the ConOps will inform and guide future system design activities, it must be kept in mind that it is meant to be living documents, i.e., to be altered to address changes in user needs, system requirements, operating environment, desired functionalities, or constraining elements.

1.4. CONTENT OF DOCUMENT

The subsequent sections of the ConOps present the following elements.

- **Section 2** (pages 7-10) presents the scope of the project. This includes a description of the project background; the boundaries of the corridor where the proposed system is to be deployed; the vision, goals, and objectives of the project; and a list of entities expected to be involved in the development and/or operation of the proposed system.
- **Section 3** (pages 11-12) lists various reference documents that were used to develop the ConOps.
- **Section 4** (pages 13-30) presents an overview of the corridor chosen for the proposed pilot ICM system. This includes a description of the jurisdictional environment, roadway networks, transit systems, parking facilities, bike networks, and trip generators within and around the corridor.
- **Section 5** (pages 31-68) presents the transportation management assets currently used to monitor and control traffic along the I-210 freeway and surrounding arterials. This includes the traffic management centers operated by Caltrans, LA County, and local cities; detection systems used to monitor freeway and arterial traffic; Caltrans' on-ramp and freeway-to-freeway connector ramp metering system, and systems used to control traffic signals at arterial intersections. This section also includes systems used by Caltrans and first responders to manage incidents and events; by transit agencies to monitor and manage their operations; and by parking operators to manage their facilities. Finally, the section describes existing traveler information systems and available dedicated communication networks for information exchanges among agencies.
- **Section 6** (pages 69-108) presents an assessment of how the corridor is currently operating. The section starts with a characterization of the demand for travel along the I-210 freeway and surrounding arterials from within and outside the corridor. A description of congestion hotspots, travel time profiles, travel time reliability, incurred delays, and safety issues for the freeway follows. The section continues with an assessment of available capacity at key intersections and a compilation of safety statistics for the arterials. It concludes with summary performance information about transit services operated within the corridor and parking occupancy rates.
- **Section 7** (pages 109-116) presents a justification for the proposed ICM system. This includes an identification of operational, informational, and institutional gaps affecting corridor operations; environmental and financial factors that may influence the project; desired operational corridor improvements; and a summary ranking of priorities among desired changes.

- **Section 8** (pages 117-140) presents the proposed ICM system concept. This first includes a description of the vision for corridor management, the goals and objectives of the proposed system, and various underlying concepts that may influence decisions regarding the development of the system. This is followed by a comprehensive list of all improvement strategies that could potentially be implemented as part of an ICM system, the description of a potential operational framework for the system, and a listing of potential system outputs.
- **Section 9** (pages 141-156) describes the various stakeholders of the proposed ICM system, and identifies their existing role(s) in the operation and management of transportation systems within the corridor.
- **Section 10** (pages 157-170) details the user needs for the system that were collaboratively developed with the corridor stakeholders, the roadway segments proposed to be managed, the system data collection needs, and some high-level operational needs and constraints that were brought forward by corridor stakeholders. Information about the need to seek compatibility with the regional ITS architecture, develop specific institutional agreements, and provide some professional capability development is also presented.
- **Section 11** (pages 171-184) presents an overview of the proposed ICM system. The section starts with a refresher on the system goals and objectives and descriptions of the general system capabilities being sought and control framework to be implemented. Key envisioned system components, a high-level system architecture, key needed interfaces with other existing systems, and important standards to consider are then detailed. A presentation of envisioned modes and states of operations follows. The section concludes by presenting an institutional framework within which the proposed ICM system is envisioned to operate.
- **Section 12** (pages 185-198) describes the envisioned operational environment of the system. This includes summary information on the facilities, transportation systems, equipment, computing hardware, software, communication networks, personnel, and operational procedures that may be used when operating the system.
- **Section 13** (pages 199-206) describes support environment of the proposed system. This includes descriptions of facilities, utilities, equipment, computing hardware, software, communication systems, cooperative agreements, personnel, and procedures that may be used to support the operation and maintenance of the proposed ICM system.
- **Section 14** (pages 207–238) presents a series of scenarios describing how the proposed system would operate in various situations. Scenarios presented include no-incident/no-event operations, moderate freeway incident, major freeway incident, major arterial incident, special event, and major transit incident.
- **Section 15** (pages 239–249) finally presents a summary analysis of how the proposed system might improve corridor operations, impact existing operational procedures, and affect the institutional organization of stakeholder agencies. Potential disadvantages and limitations of the proposed system are also presented.

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2. PROJECT SCOPE

This section presents the general scope of the I-210 Pilot, including:

- General background for the project
- Boundaries of the corridor for which the proposed ICM system is to be developed
- General vision, goals, and objectives of the system to be developed
- Entities expected to be involved in the development or operation of the system

2.1. PROJECT BACKGROUND

Throughout most of its history, the California Department of Transportation, or Caltrans, has been a freeway-centric agency. Agency activities predominantly centered on building and managing freeways. In 2011, Caltrans leadership sought to change this situation and established a new focus seeking collaboration and coordination with other agencies to maximize scarce resources, and, ultimately, to improve system-wide performance. The Connected Corridors (CC) program was developed shortly thereafter to help Caltrans achieve its new multi-modal, multi-agency collaborative vision.

Connected Corridors (CC) is an ICM program that looks at an entire transportation system and all opportunities to move people and goods in the most efficient manner possible to ensure the greatest potential gains in operational performance will be achieved. This includes seeking solutions to improve how freeways, arterials, transit, and parking systems work together. Travel demand management strategies and agency collaborations are also actively considered. The program is a collaborative effort to research, develop, test, and deploy a new framework for corridor management in California that aim to change the way state and local transportation agencies, as well as any additional entity having a stake in the operation of transportation system elements, manage transportation challenges for years to come.

Starting with a pilot on I-210 in the San Gabriel Valley, Caltrans aims to expand the application of ICM concepts to 50 corridors throughout California over the next ten years. In this context, the I-210 Pilot will serve as a test bed to demonstrate how an ICM project can be developed by engaging corridor stakeholders to build consensus on how to address congestion for the betterment of an entire network.

2.2. CORRIDOR BOUNDARIES

Figure 2-1 locates the study corridor relative to downtown Los Angeles. The central element of the corridor is a 25-mile section of the I-210 freeway (Foothill Freeway) extending from Pasadena in the west to La Verne in the east. More specifically, the section of interest extends from the Arroyo Boulevard interchange in Pasadena (Exit 22) approximately 2 miles north of the I-210/SR-134 interchange to the Foothill Boulevard/SR-66 interchange in La Verne (Exit 47) approximately 2 miles east of theI-210/SR-57 interchange. The section of I-210 west of the I-605 freeway (San Gabriel River Freeway) will be the focus of the first phase of the system deployment, while the management of the section east of the I-605 will be added in a second project phase.

As illustrated, the I-210 freeway provides a vital link between various communities in the northern end of the Los Angeles metropolitan area. From the Sylmar district at the north end of the city of Los Angeles,

Figure 2-1 – I-210 ICM Corridor Study Area

the freeway links the city of Pasadena, communities in the San Gabriel Valley and Pomona Valley and, finally, communities in the San Bernardino area. This corridor runs through a predominantly urban environment and includes the most frequently and heavily congested sections of the freeway.

South of the I-210, the study area is shown to extend to the I-10 freeway. While the proposed ICM system explicitly aims to improve operations along I-210, the close proximity of the I-10 and the presence of two interconnecting freeways (I-605 and SR-57) create some operational interdependencies between the two freeways. Incidents or events affecting operations along the I-10 often affect operations along the I-210, and vice versa. Even though the project does not aim to develop traffic and travel management strategies for the I-10, the operational interdependency between the two freeways creates a need to consider what may be happening on I-10 when developing operational strategies for the I-210 freeway.

2.3. SYSTEM VISION, GOALS, AND OBJECTIVES

The ICM system described in this document specifically aims to improve the operations of the corridor through the following approaches:

1. Improved real-time system monitoring capabilities through the utilization of emerging data collection techniques, such as probe vehicle data collection capabilities
2. Improved coordinated responses to incidents
3. Improved ability to adjust corridor operations in real time
4. Enhanced ability to influence traffic patterns and travel demand through improved data dissemination techniques
5. Implementation of improved traffic and demand management applications
6. Improved operational coordination of traffic management along freeways and arterials
7. Improved coordination of roadway and transit operations

8. Improved coordination of activities among agencies involved in the management and operation of a transportation corridor

The primary goal of the proposed system is to improve travel mobility within the corridor during incidents and events. This translates into an end goal to improve overall system performance by increasing the efficiency with which existing systems are being used, through the implementation of cross-jurisdictional traffic and demand management strategies considering all relevant travel modes within a corridor. This translates into the following specific goals:

1. Improve operational situational awareness
2. Promote collaboration among corridor stakeholders
3. Improve incident response
4. Improve travel reliability
5. Improve overall corridor mobility
6. Empower travelers to make informed travel decisions
7. Facilitate multi-modal movements across the region
8. Promote transportation sustainability by reducing impacts on the environment
9. Improve corridor safety

2.4. INVOLVED ENTITIES

Entities expected to be involved in the operation of the proposed system include all agencies operating transportation systems within the project's corridor. Key system stakeholders include Caltrans, County and City transportation agencies, transit system operators, and first responders. Additional potential stakeholders include regional planning agencies, transportation commissions, enforcement agencies, commercial fleet operations, and parking facility operators. The media and information service providers are also expected to play a significant role in engaging routine travelers, who are themselves expected to actively participate in system operations, albeit indirectly, by altering their travel choices based on information received prior to initiating a trip or while en-route.

A more detailed description of the various identified system stakeholders is provided in Section 9.

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3. REFERENCE DOCUMENTS

This section lists various reference documents that were used in the development of the ConOps.

- **Systems engineering reference documents**
  - *Intelligent Transportation System Architecture and Standards – Final Rule*, 23 CFR Parts 655 and 940, Federal Register, Vol. 66, No. 5, January 2011.
  - Federal Highway Administration and Federal Transit Administration, *Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals.* Publication No. FHWA-HOP-07-069, Federal Highway Administration, U.S. Department of Transportation, January 2007.
  - Federal Highway Administration and Caltrans, *Systems Engineering Guidebook for Intelligent Transportation Systems, Version 3.0.*, Federal Highway Administration, U.S. Department of Transportation, November 2009.
  - Federal Highway Administration, *Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) Systems.* Publication FHWA-HOP-11-027, Federal Highway Administration, U.S. Department of Transportation, August 2012.

- **ITS architecture**
  - *The National ITS Architecture 7.0*, U.S. Department of Transportation, available at http://www.iteris.com/itsarch/, released October 2012.
  - National Engineering Technology Corporation and Meyer, Mohaddes Associates, *Los Angeles County Regional ITS Architecture: Complete Final.* Document prepared for Los Angeles County, June 2004.

- **I-210 corridor system management documents**
  - System Metrics Group. *Corridor System Management Plan (CSMP): Los Angeles I-210 Corridor Final Report*. Document prepared for Caltrans and the Southern California Association of Governments (SCAG), September 2010.
  - Minagar & Associates, Inc., *I-210 Truck Origin and Destination (O-D) Study.* Report prepared for the Los Angeles County Metropolitan Transportation Authority (Metro), October 2011.

- **Regional and local transportation planning documents**
  - *2012-2035 Regional Transportation Plan,* Southern California Association of Governments (SCAG), December 2011.
  - *2009 Long Range Transportation Plan*, Los Angeles County Metropolitan Transportation Authority, 2009.
  - *2014 Short Range Transportation Plan (Draft)*, Los Angeles County Metropolitan Transportation Authority, 2014.
  - Iteris, *City of Pasadena ITS Master Plan Framework*. Document prepared for the City of Pasadena Department of Transportation, May 2012.

  - *Arcadia General Plan*, City of Arcadia, November 2010.
  - Edaw Inc. and Fehr & Peers, *Circulation Element of the Monrovia General Plan*. Document prepared for the City of Monrovia, November 2012.
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- **Technical system documents**
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  - M. Amundson, *Operating a Multi-Jurisdictional Traffic Management Center*. Traffic and Lighting Division, Los Angeles County Department of Public Works, November 2011.
  - TransCore, *Information Exchange Network (IEN): IEN System Overview Manual, Version 2.4.1*. Document prepared for the Department of Public Works of Los Angeles County and the Los Angeles County Transportation Authority (Metro), March 2012.
  - IBI Group, *Regional Integration of Intelligent Transportation Systems (RIITS): 10-Year Strategic Plan*. Document prepared for the Los Angeles County Transportation Authority (Metro), June 2010.
  - Kimley-Horn, *KITS Operator's Manual.* Document prepared for the Los Angeles County Department of Transportation, January 2006.
  - *Advanced Transportation Management System (ATMS) Overview*. Los Angeles County Metropolitan Transportation Authority, June 2012.
  - *Ramp Metering Procedure Manual Addendum*. Office of Freeway Operations, Division of Operations, Caltrans District 7, June 2005.

4. CORRIDOR OVERVIEW

This section presents a general overview of the corridor that has been selected for the development of the pilot ICM system. Elements presented include:

- Jurisdictional environment;
- Existing transportation systems;
- Trip generators located within the corridor;

For many of the above items, additional information can be found by consulting the *I-210 Connected Corridors Pilot: Corridor Description and System Inventory* document from which most of the information contained in this section was extracted.

4.1. JURISDICTIONAL ENVIRONMENT

Figure 4-1 maps the cities and unincorporated county areas located within the study corridor. To help assess the relative size of each jurisdiction, the map also lists the population of each jurisdiction or unincorporated area. The thick blue line going across the map further shows the Los Angeles County Supervisorial boundaries within the corridor. Jurisdictions north of the boundary are part of District 5, while jurisdictions on the south are part of District 1.

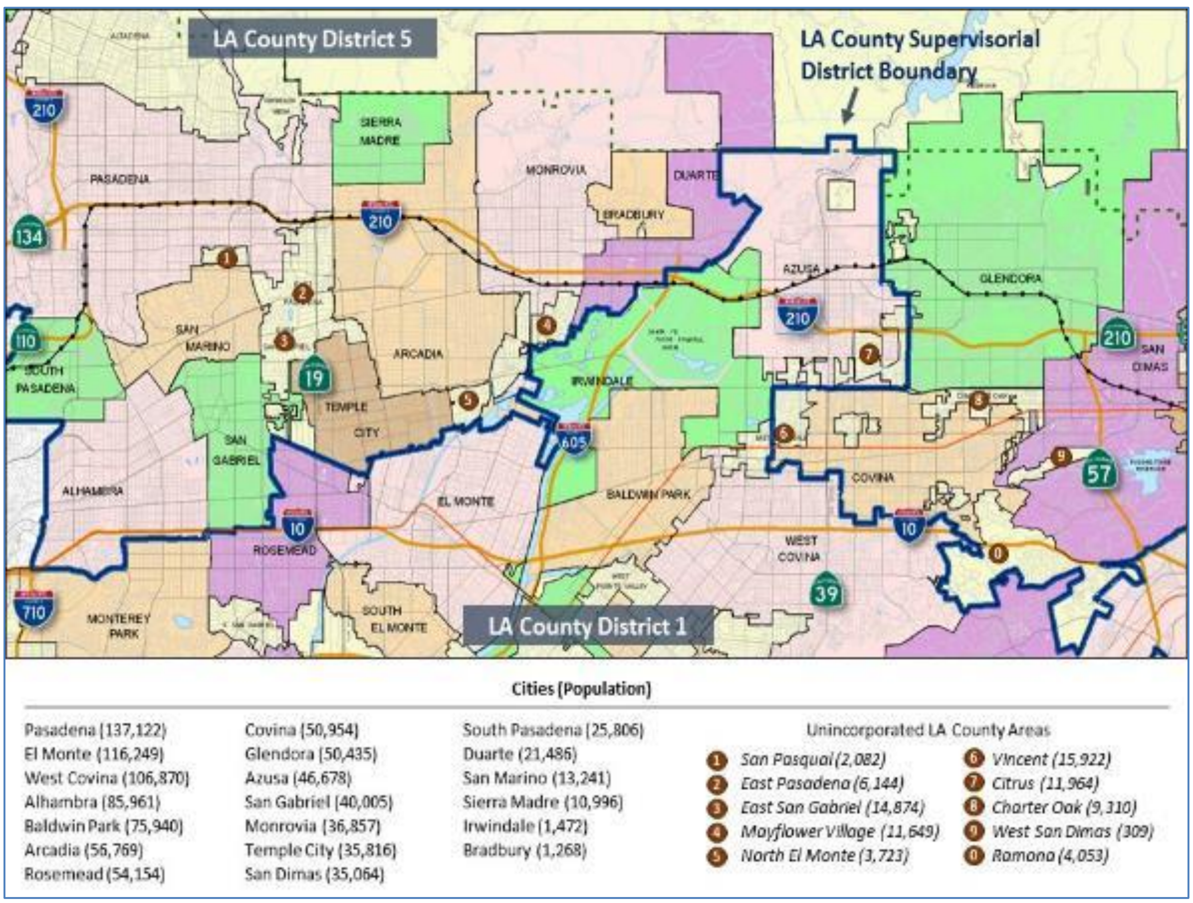

Figure 4-1 – Jurisdictional Boundaries

As shown on the map, cities directly crossed by the I-210 freeway include Pasadena, Arcadia, Monrovia, Duarte, Irwindale, Azusa, Glendora, San Dimas and La Verne. Two unincorporated areas under administration from Los Angeles County are also crossed by the freeway: the East Pasadena area between the cities of Pasadena and Arcadia, and the Citrus area between the cities of Azusa, Covina and Glendora.

Several other cities to the north and south of I-210 are crossed by arterials that may be used as detours during incidents by freeway travelers or as connecting routes to reach I-10. This includes the cities of South Pasadena, San Marino, Temple City, Sierra Madre, Baldwin Park, and Covina, as well as the cities of Alhambra, San Gabriel, and El Monte to some extent.

Given the demonstration nature of the I-210 Pilot, a strategic decision was made to consider at this stage only the coordination of transportation system elements close to the I-210 freeway. This limits the area of prime interest to transportation system elements laying within the boundaries of the cities of Pasadena, Arcadia, Monrovia, Duarte, and Irwindale, as well as the unincorporated areas of San Pasqual, East Pasadena and Mayflower Village. A decision to include transportation system elements laying in other others may be made later by the corridor stakeholders if the needs arises.

4.2. EXISTING TRANSPORTATION SYSTEMS

This section describes the various transportation systems that currently exist within the I-210 corridor. Specific elements described here include:

- Freeways crossing the project corridor
- High-occupancy vehicle facilities on freeways
- Key arterials running parallel or perpendicular to the freeways
- Routes designated as truck routes
- Routes designed as disaster routes
- Public transit services
- Park-and-ride facilities operated by various public transportation agencies
- Parking structures and surface lots supporting local retail, commercial and business activities
- Bike paths

4.2.1. FREEWAYS

As indicated in Section 2, the proposed ICM system seeks to improve the management of a 25-mile section of the I-210/SR-210 freeway (Foothill Freeway**)**. This section extends from the Arroyo Boulevard interchange in Pasadena (Exit 22B) approximately 2 miles north of the SR-134/I-210 interchange, to the Foothill Boulevard interchange in La Verne (Exit 47) approximately 2 miles east of the SR-57 interchange. The focus of the first phase of the project is on the section of the freeway west of the I-605, while the second phase will add the portion of the freeway east of the I-605.

As shown in Figure 4-2, the freeway typically provides four general-purpose traffic lanes, with additional auxiliary lanes between some interchanges. Sections west of SR-57 generally only offer three traffic lanes. In Pasadena, the I-210/SR-134 interchange further provides a break in the continuity of the freeway. At this interchange, the main east-west crossing at this interchange takes traffic from the I-210 freeway to the SR-134 freeway. The main north-south crossing takes traffic from the I-210 freeway to a

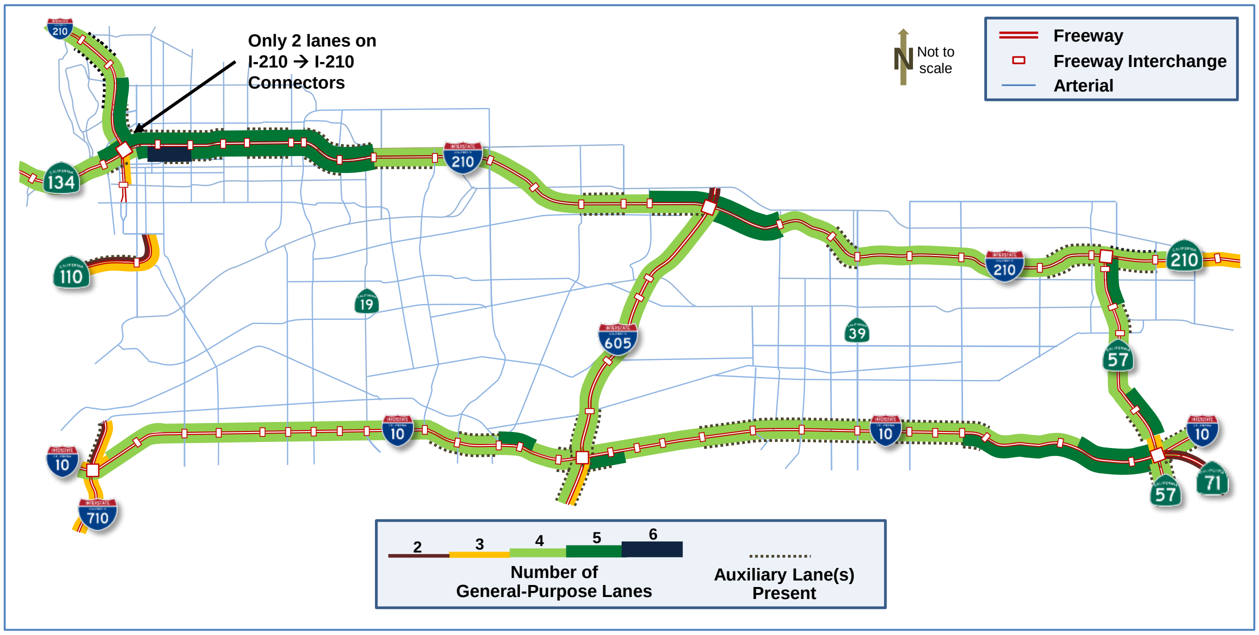

Figure 4-2 – General-Purpose Freeway Lane Configuration

short section of I-710 running on the west side of downtown Pasadena. In each direction, motorists wishing to continue traveling along I-210 must do so by traveling through a two-lane freeway connector.

Four to five miles south, the **I-10 freeway (San Bernardino Freeway)** provides an alternate route to downtown Los Angles from the communities in the San Gabriel Valley and San Bernardino area. This facility typically provides four general-purpose traffic lanes per direction within the study area, while some sections feature five traffic lanes or auxiliary lanes.

Two north-south freeways may further be used to travel between the I-210/SR-210 and I-10 freeways:

- **I-605 (San Gabriel River Freeway) –** This freeway connects the I-210 freeway near Irwindale with the I-10, SR-60, I-5, I-105, SR-91 and I-405 freeways to the south. It terminates near Seal Beach.
- **SR-57 (Orange Freeway) –** This freeway connects the I-210/SR-210 freeway near San Dimas with the I-5 and SR-22 freeways near downtown Orange to the south.

Other freeways providing connections to other areas of the metropolitan Los Angeles region include:

- **SR-134 (Ventura Freeway)** – East-west freeway linking Pasadena to the southern San Fernando Valley and Ventura County.
- **SR-110 (Arroyo Seco Parkway)/I-110 (Harbor Freeway)** – North-south freeway linking Pasadena to downtown Los Angeles, South Los Angeles, Carson and the Port of Los Angeles near San Pedro.
- **I-710 (Long Beach Freeway)** – North-south freeway linking Alhambra to East Los Angeles and Long Beach. While this freeway currently ends at the boundary between the cities of Los Angeles and Alhambra, just north of the I-10 freeway, studies are currently exploring the possibility of extending it through South Pasadena to the I-210/SR-134 interchange.
- **SR-71 (Chino Valley Freeway)** – Freeway linking the I-10 freeway, from the I-10/SR-57 interchange, to the SR-60 and SR-91 freeways to the southeast.

4.2.2. HOV/HOT FACILITIES

As indicated in Figure 4-3 both east-west freeways crossing the study corridor have HOV lanes:

- **I-210/SR-210 Freeway** – A single HOV lane is provided in each direction between the SR-134 freeway in Pasadena and the I-215 freeway in San Bernardino. At the SR-134 interchange, the HOV lanes continue uninterrupted along SR-134 and extend past the I-5 interchange up to the US-101 interchange northeast of downtown Los Angeles. Similar to other southern California freeways, HOV lane restrictions are in effect 24 hours a day, seven days a week. The HOV lanes are further separated from the general-purpose lanes by a solid double yellow line, with designed ingress/egress points. As shown in Figure 4-3, 11 ingress/egress points are provided in the eastbound direction between the SR-134 and Foothill Boulevard interchanges, while 12 points are provided in the opposite direction.
- **I-10 Freeway** – A continuous single HOV lane runs from the I-5 interchange, near downtown Los Angeles, to just west of the I-605 freeway. West of El Monte, the lane runs along the El Monte Busway. While no continuous HOV lanes currently exist between I-605 and SR-57, there are plans to close this gap to provide HOV lanes up to the I-15 freeway in the east. Between the I-710 and I-605 interchanges, eastbound traffic has three ingress and four egress points, while westbound traffic has four ingress and three egress points. This HOV lane has stricter access restriction than other Southern California freeways. During peak hours, only vehicles with three occupants or more can access it. Off peak, any vehicle with two occupants can access it. On February 2013, the HOV lanes west of the I-605 interchange were converted to High-Occupancy Toll (HOT) lanes with dynamic pricing. This change now enables vehicles that do not meet the HOV lane requirement to use the facility, but for a fee. It also resulted in a requirement that all vehicles using the facility have a valid transponder, whether or not they would be subject to a toll.

There is currently no HOV lane on freeways crossing the corridor in a north-south alignment. While HOV lanes exist along I-605, these lanes terminate just south of the I-10 interchange.

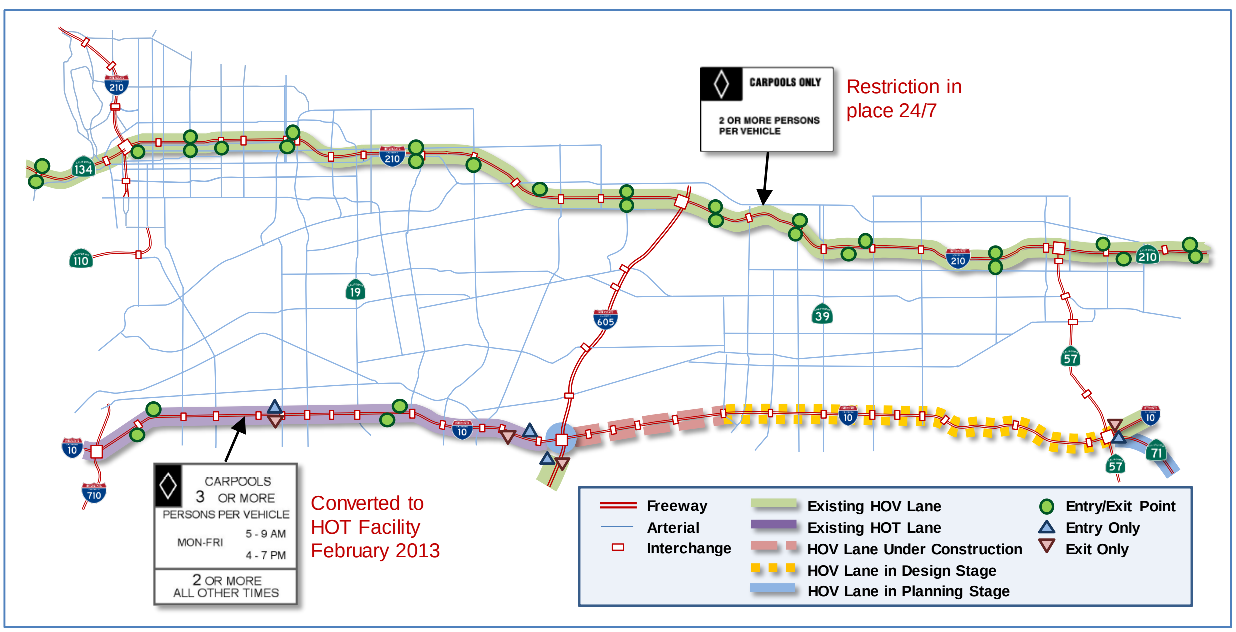

Figure 4-3 – HOV/HOT Facilities

4.2.3. SUPPORTING ARTERIALS

As shown in Figure 4-4, the following arterials, or combination of arterials, provide alternate routes parallel to the I-210 freeway within the study area:

- Orange Grove Boulevard
- Walnut Street / Foothill Boulevard
- Maple Street and Corson Street
- Colorado Boulevard / Colorado Street / Colorado Place
- Green Street and Union Street one-way couplet
- Del Mar Boulevard
- Huntington Drive
- Huntington Drive / Foothill Boulevard / Route 66 / Alcosta Avenue
- Duarte Road
- Las Tunas Drive / Live Oak Avenue / Arrow Highway
- Gladstone Street

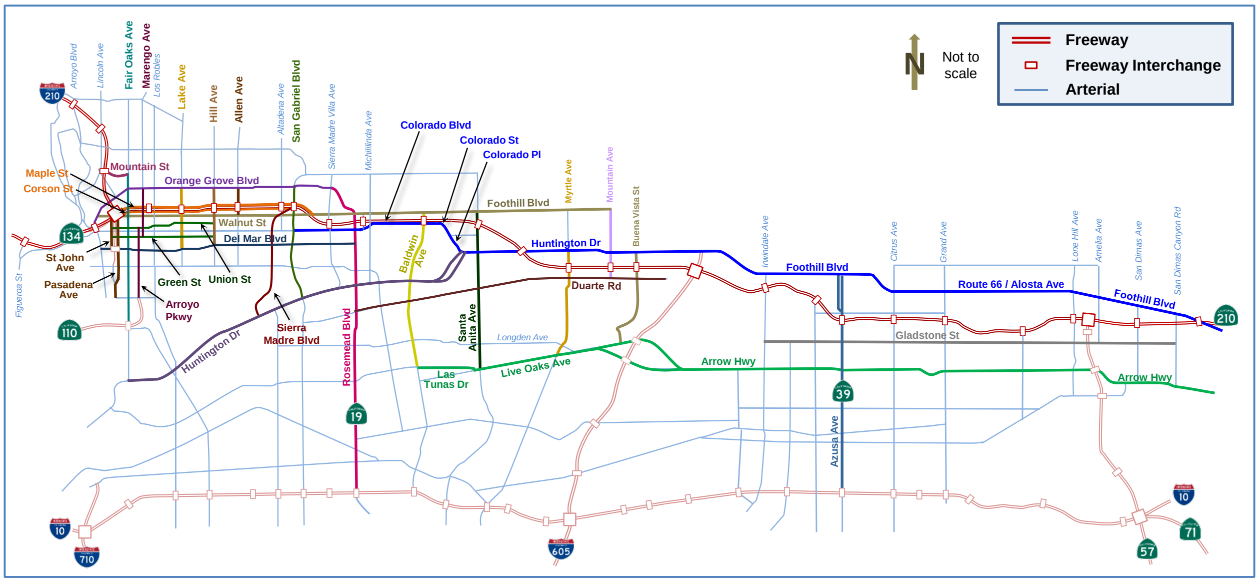

Figure 4-4 – Key Corridor Arterials

In addition to the I-605 and SR-57 freeways, several north-south arterials may be used to reach the arterials listed above from the I-210 or I-10 freeway. Key north-south arterials, from west to east, include:

- Mountain Street
- Saint John Avenue and Pasadena Avenue
- Fair Oaks Avenue
- Arroyo Parkway / Marengo Avenue
- Lake Avenue
- Hill Avenue
- Allen Avenue
- Sierra Madre Boulevard
- San Gabriel Boulevard
- Rosemead Boulevard (SR-19)

- Baldwin Avenue
- Santa Anita Avenue
- Myrtle Avenue
- Azusa Avenue (SR-39)

4.2.4. TRUCK ROUTES

Figure 4-5 maps the truck routes formally defined in city plans and regulations. These routes are identified by the bold roadway segments shown in the map. Gaps along arterials crossing unincorporated county areas are not necessarily the result of regulations prohibiting trucks. Most of the gaps are because the county administration has not formally identified truck routes for these areas. As can be observed by comparing the data of Figure 4-5 with the map of Figure 4-4, the vast majority of truck routes correspond to arterials that have been selected as potential candidates for inclusion on the proposed ICM system.

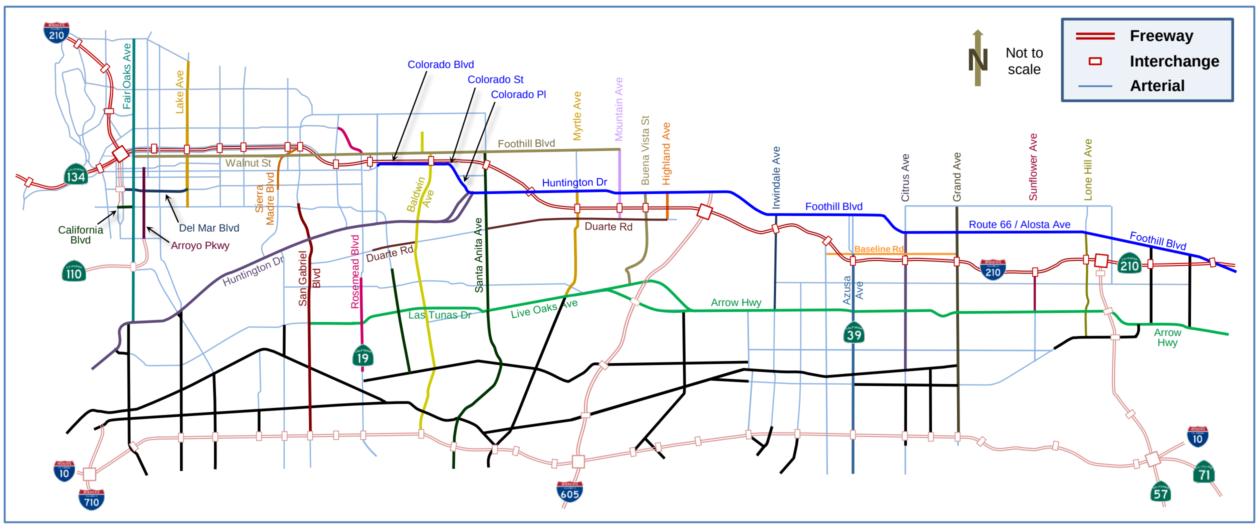

Figure 4-5 – Truck Routes

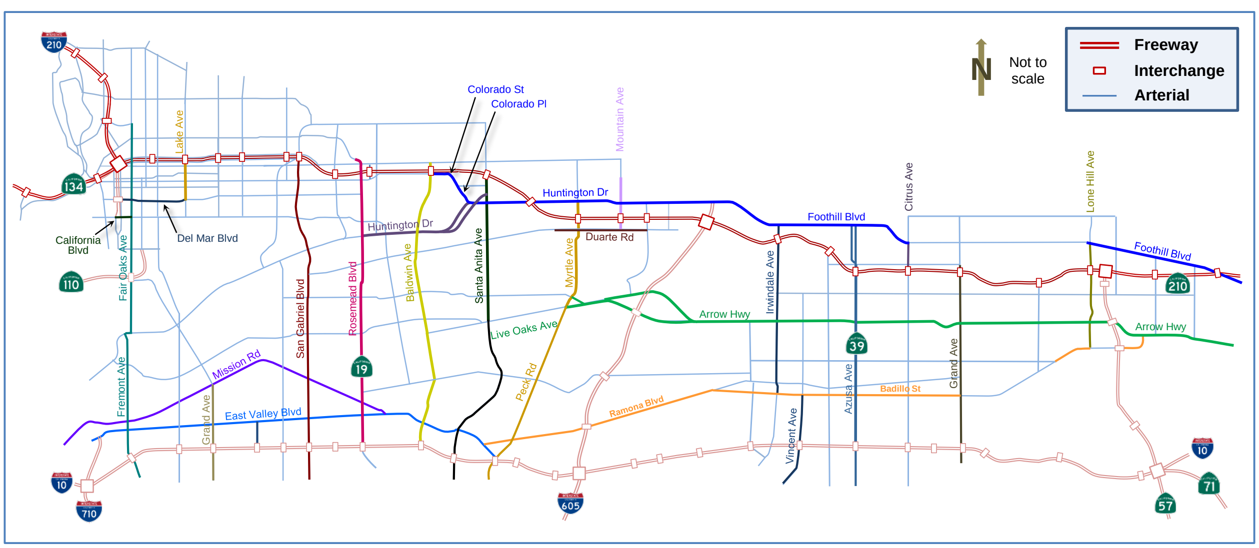

Figure 4-6 – Countywide Strategic Truck Arterial Network (CSTAN)

Figure 4-6 further shows the arterial segments included in Metro's Countywide Strategic Truck Arterial Network (CSTAN). This network was developed to assist cities in identifying truck arterial system needs and connectivity gaps, support the development of the Federal National and Primary Freight Networks, help prioritize freight-related funding to projects showing the greatest needs and system-wide benefits, minimize conflicts between trucks and pedestrians and bikes, and assist the trucking industry in identifying designed truck routes. In most cases, the CSTAN segments corresponds to segment already identified as truck routes by local jurisdictions.

4.2.5. DISASTER ROUTES

Figure 4-7 maps the routes that have been designed as disaster routes by the Los Angeles County Department of Public Works. Disaster Routes are freeway, highway or arterial routes pre-identified for use during times of crisis. These routes are utilized to bring in emergency personnel, equipment, and supplies to impacted areas in order to save lives, protect property and minimize impact to the environment. During a disaster, these routes have priority for clearing, repairing and restoration over all other roads. It should be noted that disaster routes are not evacuation routes. Although an emergency may warrant a road be used as both a disaster and evacuation route, evacuation routes are completely different. An evacuation route is used to move the affected population out of an impacted area.

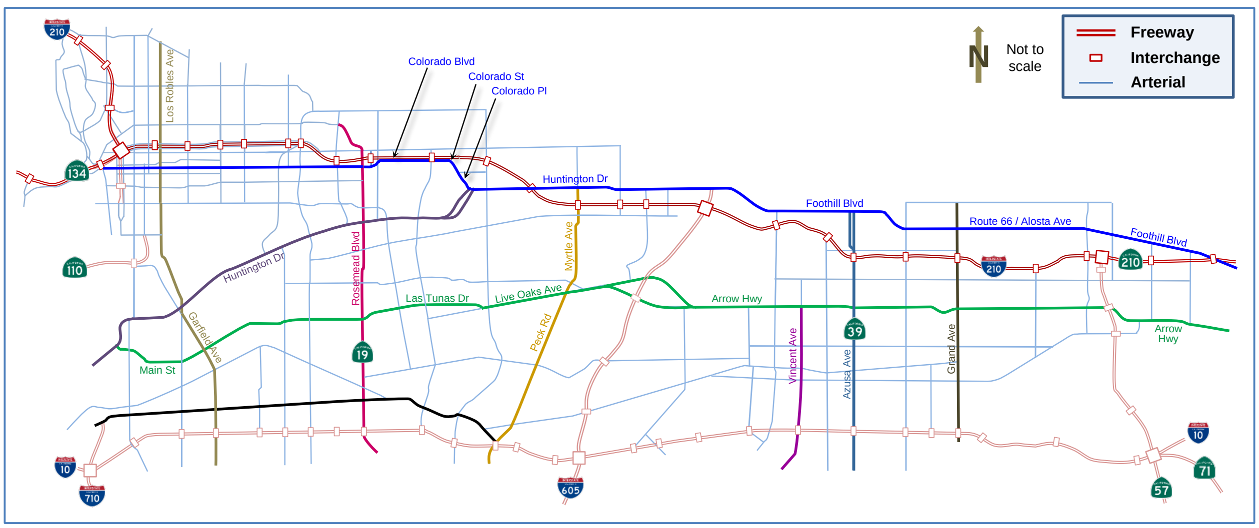

Figure 4-7 – Disaster Routes

4.2.6. PUBLIC TRANSIT SERVICES

Public transportation services offered to travelers within the I-210 corridor include the following:

- Commuter rail lines
- Light-rail transit lines
- Transitway rapid buses
- Commuter express buses
- Regional transit bus networks
- Local bus services
- Dial-a-Ride services

4.2.6.1. Commuter Rail Lines

Metrolink operates seven commuter rail lines within the metropolitan Los Angeles area. As shown in Figure 4-8, this includes one line running parallel to the I-210 corridor, mostly along the I-10 freeway. This line, known as the San Bernardino line, links downtown Los Angeles with San Bernadino to the northeast of the Los Angeles metropolitan area. This line runs all day, seven days a week, with the exception of some holidays, and has the highest service frequency within the Metrolink system. Trains typically run every 20-30 minutes during peak hour in the peak direction, and every one to two hours during off-peak periods. Within the corridor illustrated in Figure 4-8, stops are currently made at Cal State Los Angeles, El Monte, Baldwin Park, and Covina. Recently, proposals have also been floated to add a new station in San Dimas, south of the planned Metro Gold Line San Dimas station.

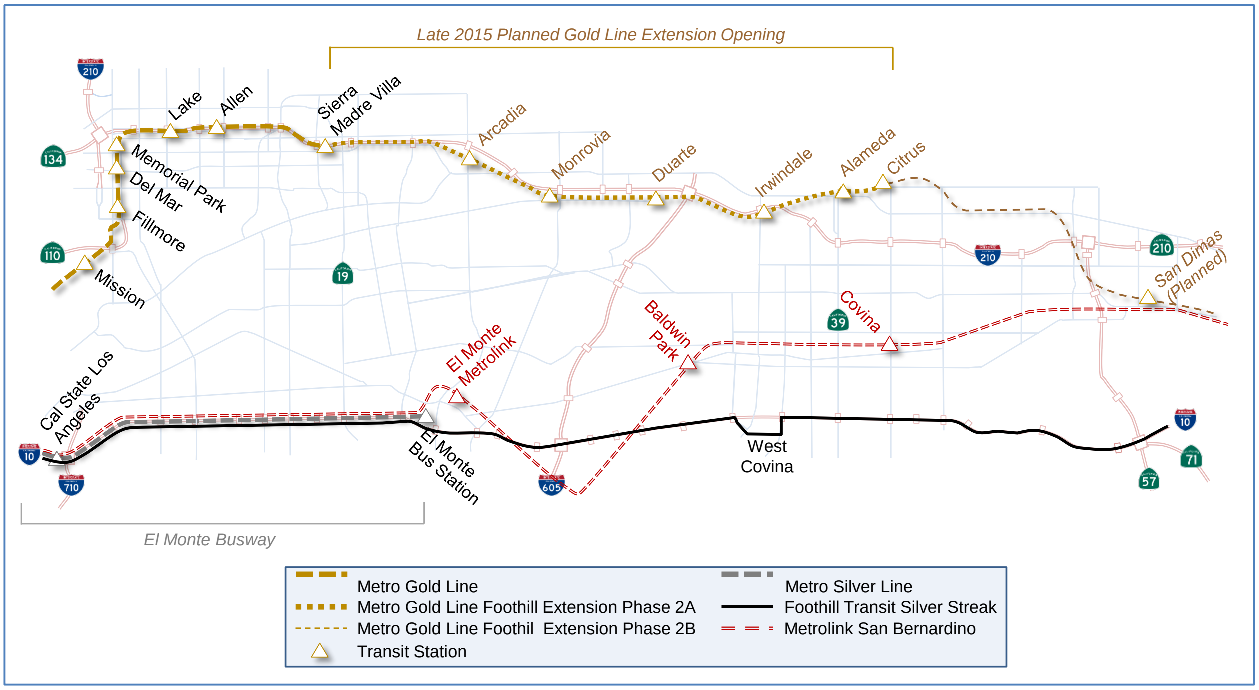

Figure 4-8 – Commuter Rail, Light-Rail, Bus Rapid Transit Services

4.2.6.2. Light-Rail Transit Lines

The western portion of the I-210 corridor is currently served by Metro's Gold Line. This light-rail line was opened in 2003 and links downtown Pasadena with downtown Los Angeles and East Los Angeles. Its location is shown in the upper portion of Figure 4-8. Under normal operating conditions, trains operate along this line from 4 AM to 1 AM, with service approximately every 6 minutes during peak periods and weekends, 12 minutes during midday, and 20 minutes during other periods. Gold Line trains typically have two cars, except in the evening and weekends, when one-car trains are used. Each car can seat 76 passengers and can carry up to 144 passengers, including standing passengers. This results in a nominal carrying capacity of 2,880 passengers per hour per direction when considering a peak service interval of 6 minutes and the use of two-car trains.

While the line currently ends at the eastern end of Pasadena, a project seeking to extend the line in phases by another 24 miles is currently underway. The first phase will extend the line by 11.5 miles from its current terminal at the Sierra Madre Villa station to a new terminus at the eastern end of the City of Azusa.

Construction began in 2011 and has an expected completion date in late 2015. The second phase, which is currently under study, proposes to extend the line by an additional 12.3 miles to Montclair.

4.2.6.3. Transitway Rapid Buses

South of the I-210, both Metro and Foothill Transit operate limited stop bus services along the El Monte Busway, a shared-used transitway and high-occupancy vehicle facility running along I-10 between the Los Angeles Union Station and the El Monte bus terminal. Both services are described below and are mapped in the bottom half of Figure 4-8:

- **Metro Silver Lane** – Service running every 4 to 8 minutes during peak hours, every 15 minutes during the midday, 20 minutes on Saturdays, 30 minutes on Sundays and holidays, and every 30 to 40 minutes during evenings.
- **Foothill Transit Silver Streak** – Express bus service between the Montclair Transportation Center and downtown Los Angeles via I-10 using high-capacity, 60-foot long articulated buses during peak hours and 42-foot long single-body buses during off peak periods. Buses on this line typically operate with an 8-minute frequency during peak hours, a 20-minute frequency during weekday off-peak periods, and a 30-minute frequency during weekends.

4.2.6.4. Commuter Express Buses

Figure 4-9 maps the commuter express bus routes operated by Metro, Foothill Transit and the Los Angeles Department of Transportation (LADOT) within or close proximity of the I-210 corridor. Key express routes linking areas of the corridor to downtown Los Angeles include Foothill Transit's Routes 481, 498, 499 and 699; and Metro's Routes 485, 487 and 489. Foothill Transit Route 690 further links downtown Pasadena to Montclair, LADOT Commuter Express 549 to Glendale and the San Fernando Valley, Metro Route 762 to Compton, and Metro Rapid 780 to the Hollywood area.

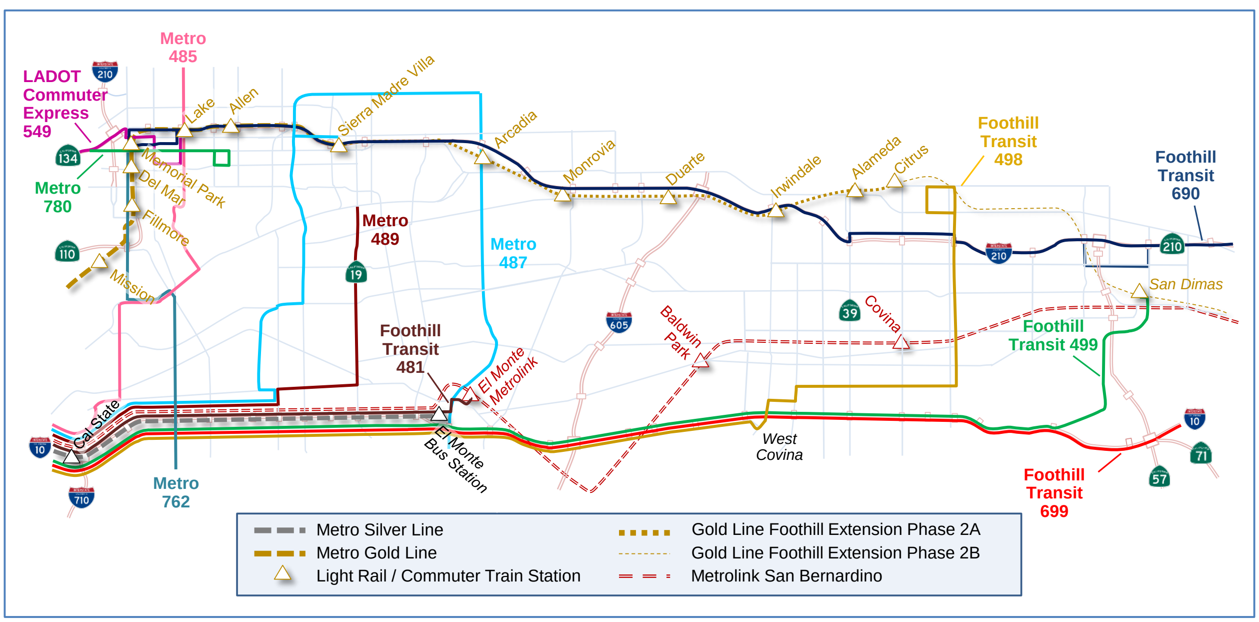

Figure 4-9 – Express Bus Services

To reduce travel times, many of the express bus routes include some freeway travel, primarily along I-10, and a limited number of stops on select off-freeway segments. All of the express routes further only operate during weekday peak hours in the peak travel direction.

4.2.6.5. Regional Transit Bus Networks

Two major transit agencies provide local bus within communities of the I-210 corridor:

- **Foothill Transit** - Primary transit service provider for the San Gabriel and Pomona Valley area. The agency operates 29 bus lines within the area, primarily east of I-605, with some lines providing connecting service to downtown Pasadena and the El Monte Metrolink station.
- **Metro** - Largest transit operator within Los Angeles County, with 190 bus lines operated over a 1,433 square mile area. Within the I-210 corridor, buses run primarily through the cities of Pasadena and Arcadia, as well as communities to the south and the west of these two cities.

4.2.6.6. Local Fixed Bus Services

In addition to the regional transit services provided by Foothill Transit and LA Metro, several cities within the I-210 corridor also provide local fixed transit services to their residents. Table 4-1 provides a summary of the transit services provided. Many of the routes offered are designed to allow city residents to access key city services or main commercial areas, or to facilitate access to regional transit services.

Table 4-1 – Fixed Local Bus Transit Services

Name	Operator	Routes	Weekday Service	Saturday Service	Sunday Service
Pasadena Transit	City of Pasadena	8	6:00 AM to 8:00 PM	11:00 AM to 8:00 PM	None
Duarte Transit	City of Duarte	3	7:00 AM to 7:00 PM	None	None
Gateway Coach Round-A-Bout	City of Sierra Madre	1	11:30 AM to 1:30 PM	None	None
Alhambra Community Transit (ACT)	City of Alhambra	2	8:00 AM to 5:00 PM	8:00 AM to 4:30 PM	8:00 AM to 4:30 PM
El Monte Transit	City of El Monte	5	6:00 AM to 7:00 PM	9:40 AM to 7:00 PM	None
Baldwin Park Transit	City of Baldwin Park	2	6:00 AM to 7:00 PM	8:00 AM to 5:00 PM	9:00 AM to 4:00 PM
Rosemead Explorer	City of Rosemead	2	5:00 AM to 8:00 PM	10:00 AM to 5:00 PM	10:00 AM to 5:00 PM

4.2.6.7. Dial-a-Ride Services

Many cities provide curb-to-curb transportation services that typically do not follow fixed routes or fixed schedules. Similar to taxi or airport shuttle services, customers are asked to phone a call center and make a reservation for a ride in advance. Reservations can typically be made for travel within a defined geographical area. While many cities restrict these services to seniors and persons with disabilities, others allow any individual residing within a given area to use the service. Cities currently offering Dial-a-Ride services include Pasadena, South Pasadena, Arcadia, Sierra Madre, Monrovia, Azusa, Glendora, Temple City, Alhambra, San Gabriel, Baldwin Park, Covina, and West Covina. Dial-a-ride services are also provided in San Dimas and La Verne by the Pomona Valley Transportation Authority, as well as the Los Angeles County Access Services for county where local dial-a-ride service is unavailable.

4.2.7. PARK-AND-RIDE FACILITIES

Figure 4-10 maps the park-and-ride facilities currently in operation or under construction within the corridor. Thirty-three facilities are shown, distributed among the following operators:

- Facilities operated by Metro along the existing Gold Line
- Facilities under construction along the Metro Gold Line extension to be operated by Metro
- Facilities near Metrolink commuter rail stations respectively operated by the cities of El Monte, Baldwin Park and Covina
- Facilities operated by Caltrans along the I-210 and SR-57 freeway
- A facility operated by the County of Los Angeles along I-10 near west of the SR-57 interchange
- Various facilities operated by cities or by private entities (e.g., colleges, malls, churches) through cooperative agreements with public transportation agencies

Parking at most facilities is on a first-come, first-served basis, except for a few facilities along the Metro Gold Line, marked by a red "R" sign in Figure 4-10, where a small number of spaces can be reserved prior to arriving at the facility.

Parking is also generally free of charge. The only facilities where a fee is charged are indicated by a red dollar sign in Figure 4-10. Where daily parking is on a first-come, first served basis, a flat daily fee of $2 or $3 is typically charged. Where parking spaces can be reserved in advance for a single day, a $3 fee is charged. Along the Gold Line, a monthly parking permit guaranteeing the availability of a parking space before 10:30 AM further costs $28 or $29, depending on the station. At the Metrolink facilities, frequent park-and-ride users can further purchase a monthly parking pass for $10 to $45, depending on the location of the parking facility and residency status of the person requesting the pass.

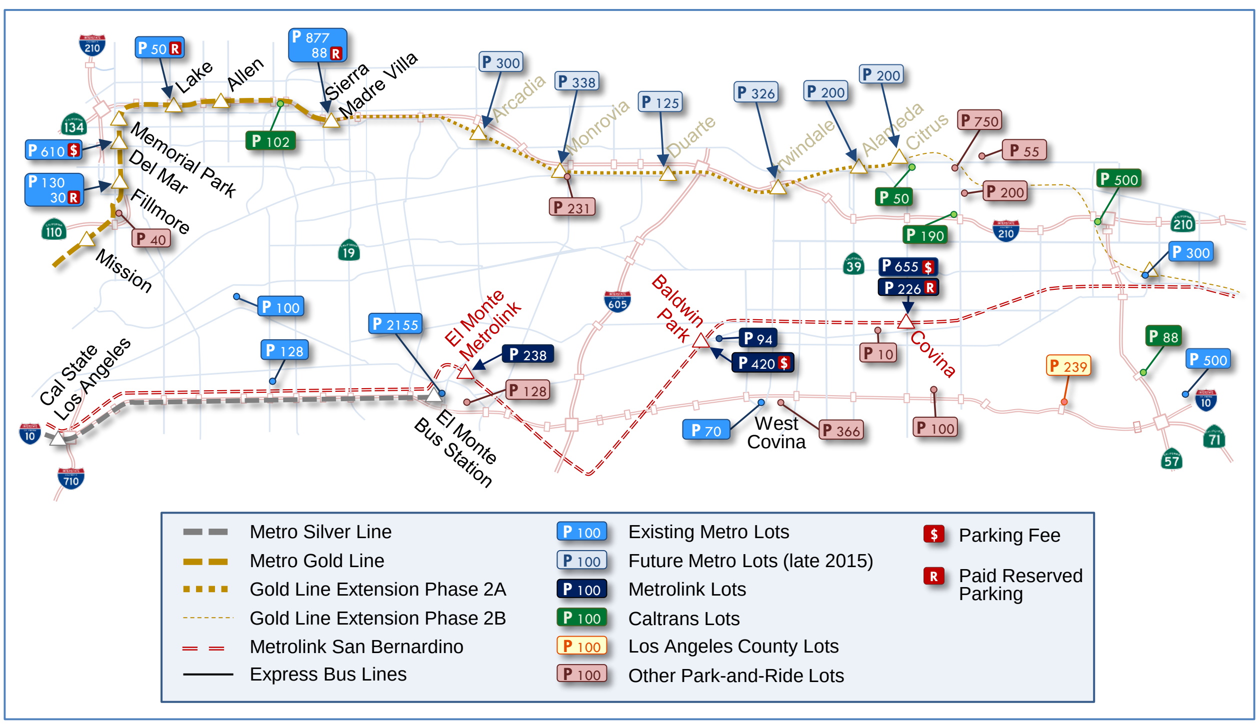

Figure 4-10 – Park-and-Ride Facilities

4.2.8. GENERAL PARKING FACILITIEs

General parking facilities include city-operated and private off-street facilities that motorists may use to park their vehicle near business, commercial, retail, and educational areas. Most of these facilities are found around downtown Pasadena. A few additional facilities are sprinkled throughout the corridor around major event venues, regional commercial centers, and local commercial and business areas.

In downtown Pasadena, many of the garages are fully utilized by employees of adjacent businesses holding monthly parking permits and only operate from Monday through Friday. However, several facilities also operate as public parking on nights and weekends. Many facilities further sell monthly permits for residents who do not have off-street parking, while some garages offer preferential parking for City employees, emergency services, or electric vehicles.

Most of the mapped facilities charge an hourly fee for parking. Public parking facilities generally offer lower rates than private facilities, and often offer free parking for the first 60 to 90 minutes. Across all types of facilities, hourly fees vary from $1 to $10. Many facilities also have a fixed daily rate or a maximum daily fee. Depending on the location and the operator, daily parking fees are typically capped between $5 and $10. Only a few private facilities have daily maximum fees exceeding $10.

While many cities own parking facilities, they are often operated by a private operator. For instance, while the City of Pasadena owns several parking garages, their operation is contracted out to private firms on five-year contracts. These private operators are responsible for staffing the parking payment booths during the hours of operations of each garage.

4.2.9. BIKE PATHS

Figure 4-11 maps the bike paths within the I-210 corridor. Several types of bike paths are distinguished:

- Class I – Paved path within an exclusive right-of-way.
- Class II – Signed and striped lanes within a street right-of-way.
- Class III – Preferred routes on existing streets identified by signs only.

Figure 4-11 – Bike Paths

As can be observed, the majority of bike paths within the corridor are Class III facilities. Most of these are found in the cities of Pasadena, Monrovia, Duarte, Glendora and San Dimas. Several Class II bike paths can also be found along select arterial sections. All Class I bike paths are off-street facilities that were developed along former railroad right-of-way or along regional park trails.

4.3. TRIP GENERATORS

Recurring trip patterns within the corridor, whether daily, weekly, monthly or yearly, are strongly influenced by the trip generators located within and around the corridor. This section provides a summary description of the following key trip generators around the I-210 corridor:

- Commercial areas
- Industrial areas
- Educational institutions
- Medical centers
- Event venues

4.3.1. COMMERCIAL AREAS

Figure 4-12 maps the main commercial and industrial areas within the corridor. Commercial areas include areas with retail activities and areas where professional office buildings are located. As can be observed, commercial areas are spread throughout the corridor, with local clusters in or near the downtown area of each city. However, downtown Pasadena is generally viewed as a major regional employment and commercial center.

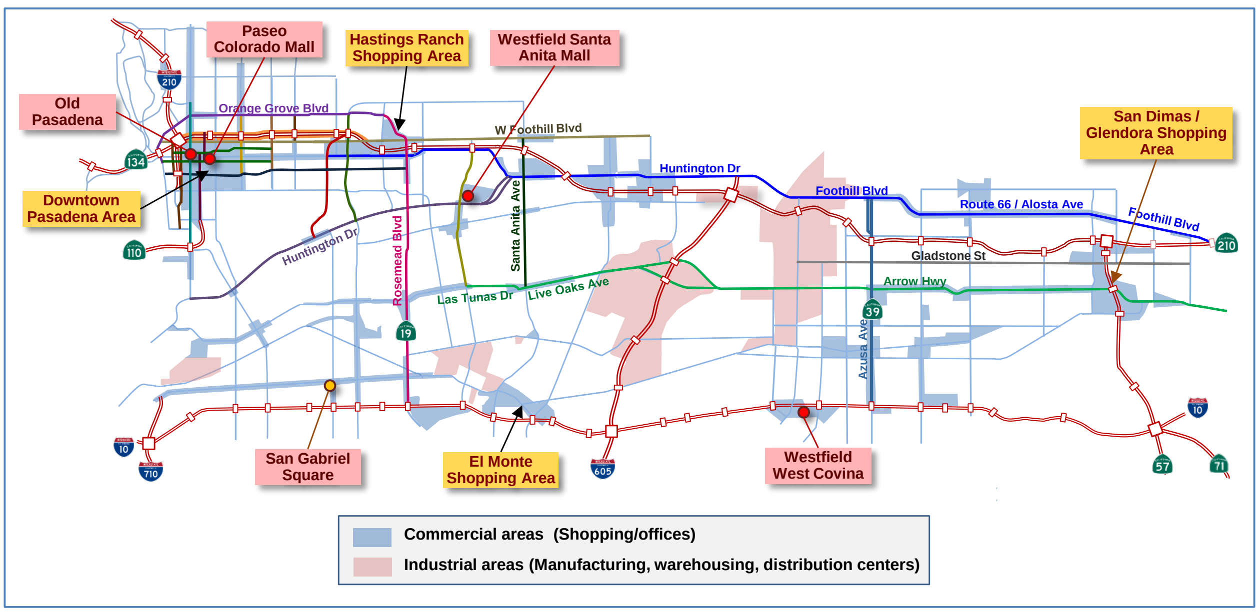

Figure 4-12 – Commercial Areas

4.3.2. INDUSTRIAL AREAS

Figure 4-13 maps the areas where several warehouses and distribution centers are located. Because of their nature, these areas likely act as origin or destination points for trips made by a significant portion of heavy and light-weight distribution trucks traveling within the corridor. Five specific areas with a high number of warehouses and distribution centers are identified in the map. Outside these five areas, general trucking companies, both commercial and private, are dispersed evenly throughout the corridor, with most of the companies operating out of offices located along Foothill Boulevard north of I-210 and along Arrow Highway/Live Oak Avenue south of I-210.

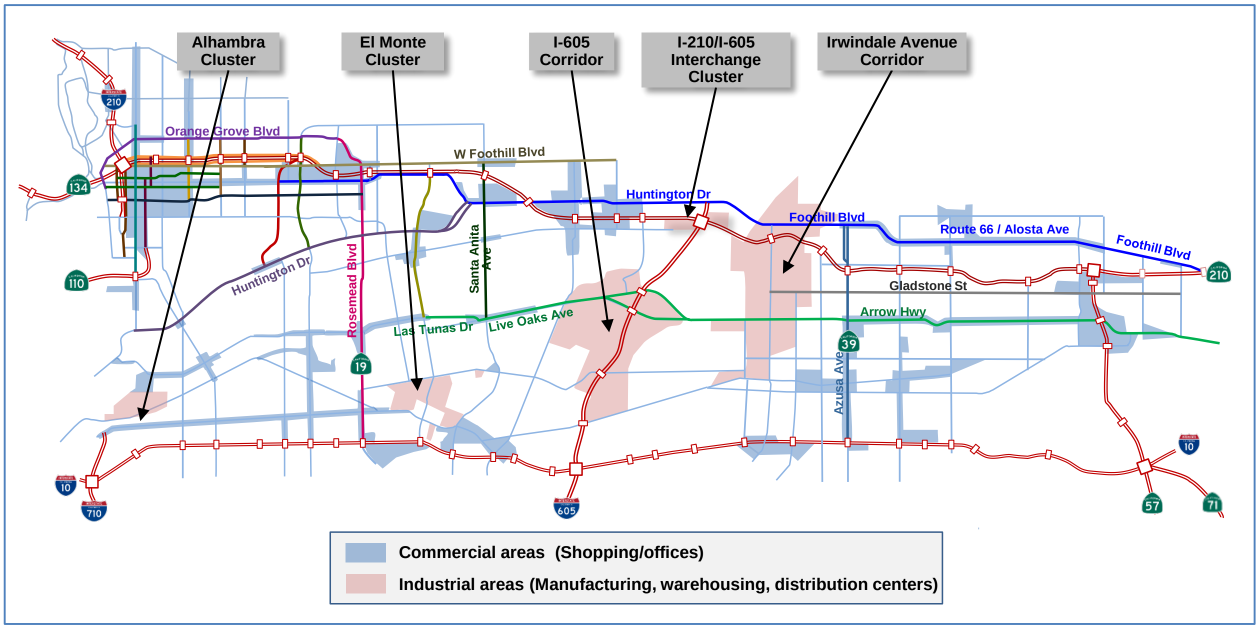

Figure 4-13 – Industrial / Warehouse Areas

4.3.3. EDUCATIONAL INSTITUTIONS

Universities and colleges can generate significant traffic to and from their campuses, particularly early in the morning and early evening, when multiple classes often start at the same time, and late afternoon and late evening, when classes end. Key institutions within the corridor or in close proximity, with the typical number of students attending, are mapped in Figure 4-14.

Figure 4-15 further maps the public and private elementary, middle and high schools within the study area. While large educational institutions can account for a significant portion of trips within the corridor, elementary, middle and high schools also generate a certain amount of trips. While the number of trips generated is smaller than large institutions, these trips tend to all occur at the same time, i.e., when school starts and ends. Depending on local conditions, such a sudden surge in traffic, couple with crossing guards periodically stopping traffic to let students cross arterials, schools may significantly affect traffic operations on streets and arterials near each school.

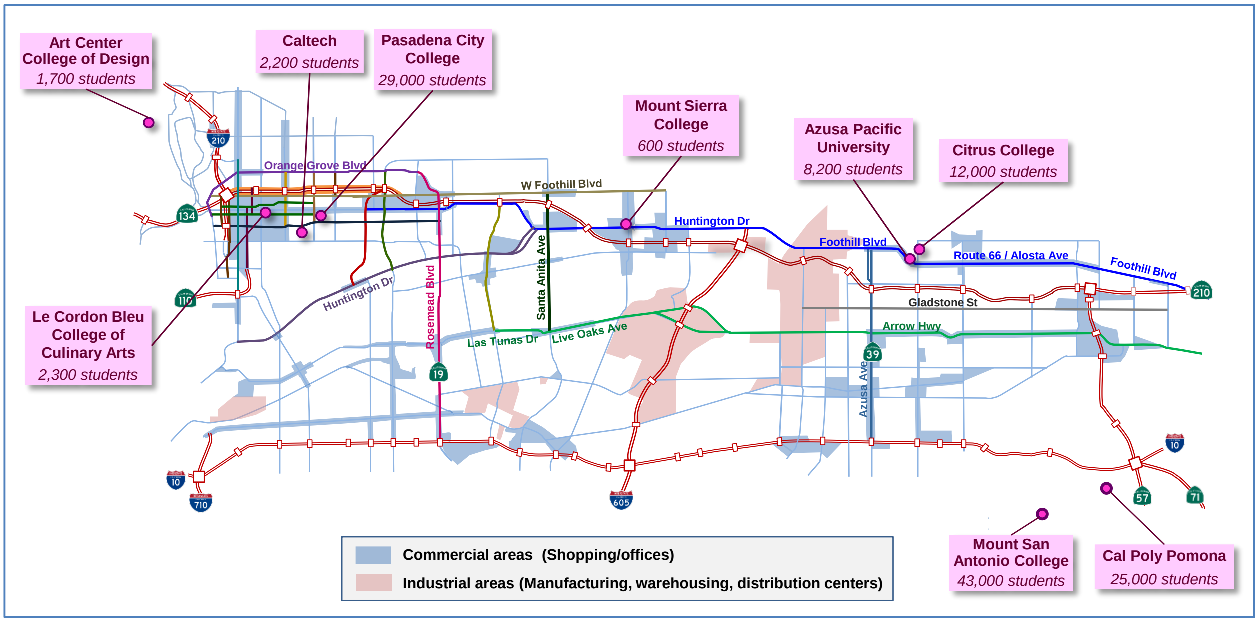

Figure 4-14 – Universities and Colleges

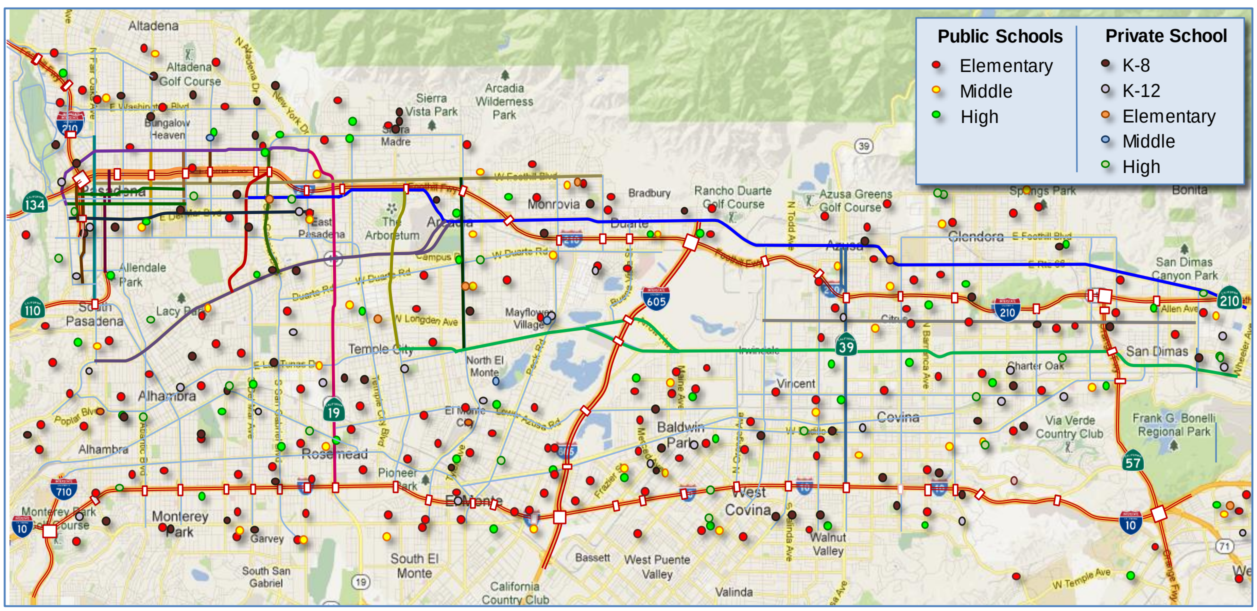

Figure 4-15 – Public and Private Elementary, Middle, and High Schools

4.3.4. MEDICAL CENTERS

Major medical centers within the I-210 corridor are mapped in Figure 4-16. While these establishments do not typically generate a large rush of traffic, the coming and going of patients and visitors may generate noticeable traffic around them. Ambulances equipped with devices enabling them to preempt traffic signals may also cause significant disruptions to traffic patterns.

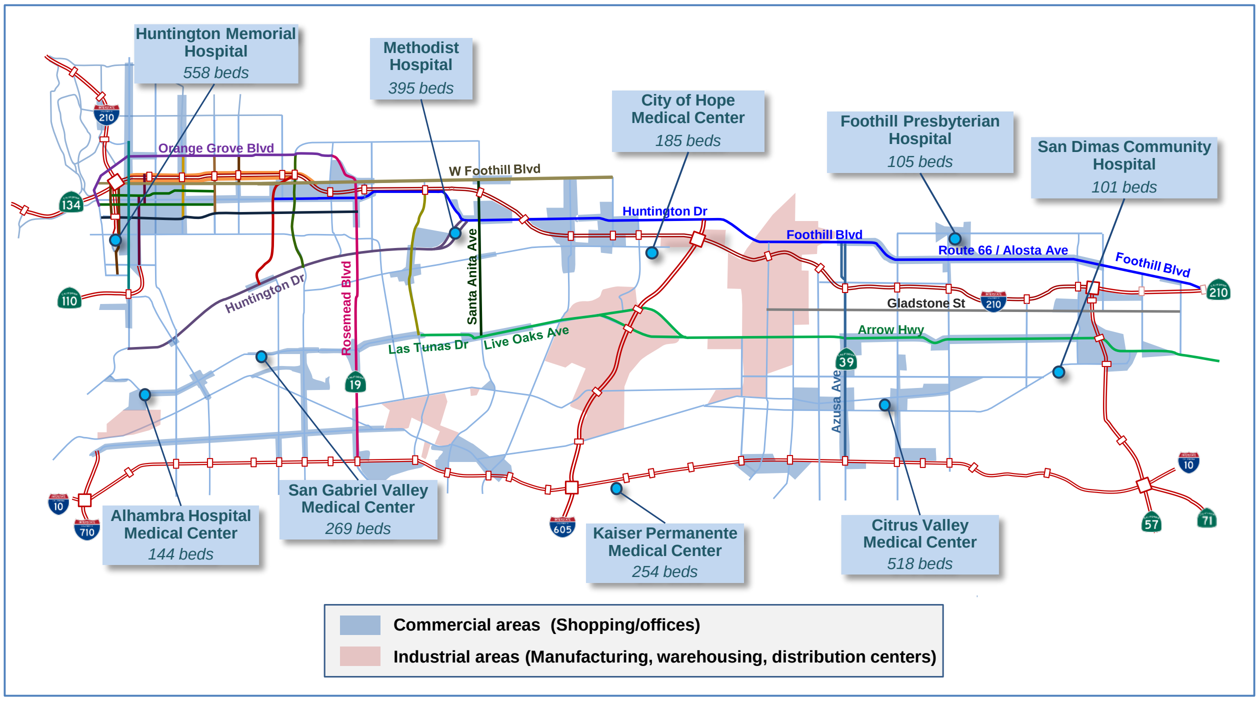

Figure 4-16 – Major Medical Centers

4.3.5. EVENT VENUES

Figure 4-17 maps major event centers and facilities that can on occasion generate unusual traffic or large traffic surges. The mapped facilities include:

- **Rose Bowl Stadium** – 90,000 seat stadium located northwest of the I-210/SR-134 interchange. This stadium is the home of the Tournament of Roses Football Game, UCLA Bruin Football, Fourth of July celebrations, concerts, religious services, filming, and the World's Largest Flea Market. Its parking lots are also available for a wide variety of rental uses.
- **Rose Bowl Aquatic Center –** Olympic-size pool located south of the Rose Bowl Stadium periodically hosting regional, statewide and national swimming competitions.
- **Santa Anita Park** – Thoroughbred racetrack hosting some of the prominent racing events in the United States during the winter and spring. The facility includes a 1,100-foot long grandstand that can seats 26,000 guests. The track infield area, which resembles a park, can accommodate an additional 50,000 guests.
- **Pasadena Convention Center –** Multi-purpose facility including a divisible 55,000 square foot exhibit hall, a divisible 25,000-square-foot ballroom, 29 meeting rooms, and a 3,000-seat multi-purpose auditorium located in downtown Pasadena.
- **Raging Waters Water Park** – 23-acre amusement park located on the north end of the Bonelli Regional Park, about three miles south of the I-210/SR-57 junction. It is the largest water park in California.
- **Irwindale Event Center** – Motorsport facility with 1/2-mile and 1/3-mile oval racetracks, in addition to a 1/8-mile drag strip, offering fixed seating accommodations for 6,500 spectators.

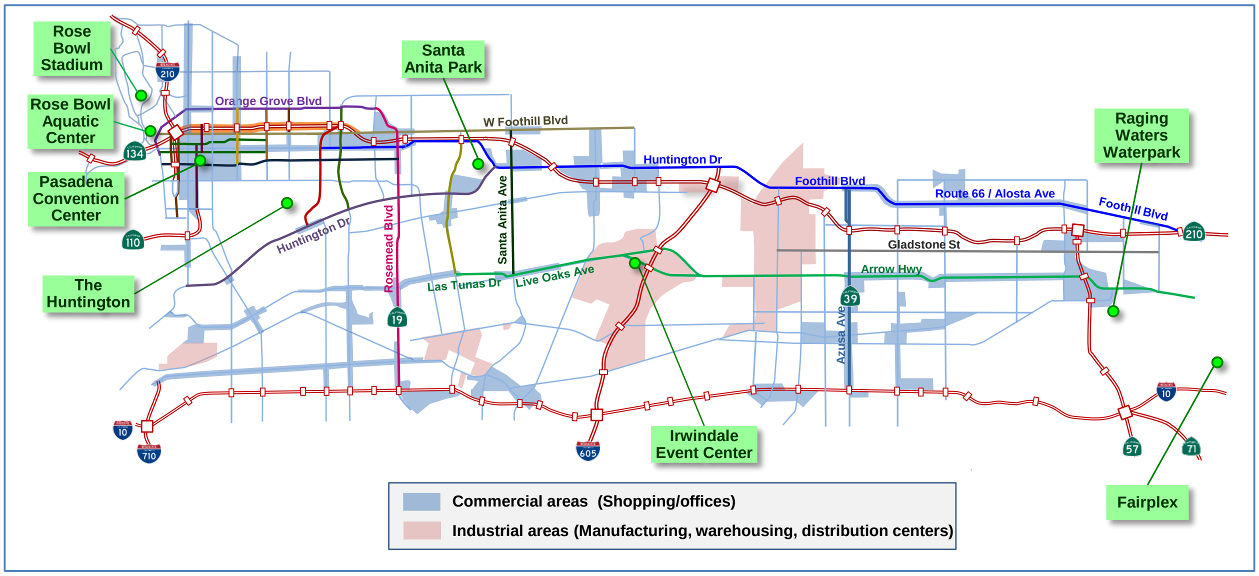

Figure 4-17 – Event Venues

- **The Huntington** – Private nonprofit institution located three miles south of I-210 in San Marino with a research library, an art gallery, and a botanical garden.
- **Los Angeles County Arboretum and Botanical Garden** – 127-acre arboretum, botanical garden, and historical site located in Arcadia, near the Santa Anita Park.
- **Fairplex** – 543 acres facility with 325,000 square feet of indoor exhibit space and a 30,000-vehicle parking capacity owned by Los Angeles County and used year-round to host a variety of educational, commercial, and entertainment events, including the annual Los Angeles County Fair held each September.

In addition to the above facilities, various local events may generate additional trips within the corridor or cause significant disruptions to normal traffic patterns. Among the most notable events are:

- **Tournament of Roses Parade –** Parade held each year on New Year's Day on Colorado Boulevard in downtown Pasadena. Attendance figures for the parade have oscillated around 700,000 individuals since 2009.
- **Pasadena Marathon** – Marathon and bike race held annually within the city of Pasadena in June, with a free festival held on the day of the race on the campus of the Pasadena City College.
- **Art Night** – Night during which several museums within Pasadena offer free admission. Art nights typically happen twice a year, one in March and the other in October.

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5. EXISTING TRANSPORTATION MANAGEMENT ASSETS

This section describes existing transportation management assets and Intelligent Transportation Systems (ITS) assets supporting the operation of transportation systems and management of transportation activities within the study corridor. Elements reviewed in this section include:

- Traffic management centers
- Traffic monitoring systems
- Freeway traffic management systems
- Arterial traffic management systems
- Incident/event management systems
- Transit management systems
- Parking management systems
- Traveler information systems
- Information exchange networks

For many of the above items, additional information can be found by consulting the *I-210 Connected Corridors Pilot: Corridor Description and System Inventory* document. Most of the information contained in this section was extracted from this document.

5.1. TRAFFIC MANAGEMENT CENTERS

Several traffic management centers (TMCs) current support the management of traffic operations within the I-210 corridor:

- Los Angeles Regional Transportation Management Center (LARTMC)
- Los Angeles County Traffic Management Center
- Pasadena Traffic Management Center
- Arcadia Traffic Management Center
- Upcoming county-hosted centralized signal control for Duarte and Monrovia

5.1.1. LOS ANGELES REGIONAL TRANSPORTATION MANAGEMENT CENTER (LARTMC)

The Los Angeles Regional Transportation Management Center (LARTMC) is a facility jointly operated by Caltrans and the CHP. Located next to the SR-2/SR-134 interchange and staffed 24 hours a day, seven days a week, this center was designed to help Caltrans staff manage traffic within the highly congested Los Angeles and Ventura County regions.

Figure 5-1 – Los Angeles Regional Transportation Management Center

At the heart of the TMC is an Advanced Traffic Management System (ATMS) that was developed by Delcan. This system enables TMC operators to monitor traffic conditions on regional freeways and to control various traffic management devices through a high-level, graphical user interface. Key functionalities supported by the LARTMC ATMS include:

- Collection and processing of traffic data from over 10,000 inductive loop detectors spread across 1280 traffic detection stations along 525 miles of freeway
- Ability to display traffic sensor data on electronic video map displays
- Access to video feeds from 350 CCTV cameras
- Management of messages displayed on 109 changeable message signs
- Management of messages broadcasted on 15 highway advisory radio stations
- Operational control of 960 ramp and connector meters
- Link to Caltrans' lane closure tracking system
- Direct access to the CHP's Computer-Aided Dispatch (CAD) system
- Automated incident detection system
- Event response decision support system
- Access to a traffic data archive covering at least five years
- Access to real-time data portals with other regional agencies
- Automated report generation functions

5.1.2. LOS ANGELES COUNTY TRAFFIC MANAGEMENT CENTER (LACTMC)

The Los Angeles County Traffic Management Center, located in Alhambra, started operations in 2005 and houses the staff and equipment needed to operate, manage, and maintain traffic signals along the major arterials in Los Angeles County. Key functionalities of this TMC include:

Figure 5-2 – Los Angeles County Traffic Management Center

- Ability to monitor and control remotely the operation of traffic signals connected to the Kimley-Horn Integrated Transportation System (KITS) server. This system, which was initially deployed in 2004 and gradually expanded since then, now enable county staff to manage over 700 signalized intersections across county areas and within cities for which a maintenance agreement has been made with the County. Within the I-210 corridor, this includes the cities of El Monte, San Gabriel and Temple City. For the future, it is envisioned that over 900 signals will eventually be connected to the system.

- Hosting the Information Exchange Network (IEN), which enables participants to monitor traffic signal operations in adjacent jurisdictions. Within the I-210 corridor, this network currently enables County staff to monitor traffic signal operations within the cities of Pasadena, Arcadia, and Alhambra.

- Access to video feeds from more than 30 CCTV cameras.

Two or three individuals from the Traffic and Traffic Systems sections of LA County are normally assigned to the TMC. The facility is typically staffed from 7:00 AM to 9:30 AM and from 2:00 PM to 5:15 PM during weekdays, as well during special events.

5.1.3. CITY OF PASADENA TRAFFIC MANAGEMENT CENTER

The City of Pasadena TMC is located in the city's administrative building. Launched in 1992, this center allows city staff to:

- Monitor and control in real time over 300 traffic signals operated under the city's i2tms, QuicNet Pro, TransCore Series 2000, and SCATS traffic signal control systems.
- Control a network of 10 CCTV cameras
- Post messages on 11 changeable message signs installed along key arterial segments.

Figure 5-3 – Pasadena Traffic Management Center

Three individuals from the Traffic Operations Division are normally assigned full-time to the TMC. They staff the TMC from 7:30 AM to 6:30 PM on weekdays, as well as during special events. While on duty, they are tasked to operate and dynamically adjust, when necessary, the signal timings at individual intersections to improve traffic flow. This is done through workstations connecting the TMC to the various controlled intersections.

While the TMC has been mainly used to support traditional traffic signal operations, there has been growing interest in enhancing its ability, including developing abilities to support more adaptive signal operations and to provide information to travelers.

5.1.4. CITY OF ARCADIA TRAFFIC MANAGEMENT CENTER

The City of Arcadia TMC is located in the city's administrative offices. This center consists of a workstation connected to large display monitors mounted on the wall. This workstation is used by city staff to:

- Monitor and control signalized intersections connected to the city's centralized TransSuite traffic control system
- Access and manage video feeds from a network of 18 CCTV cameras
- Track travel times between key intersections through data collected by a network of 15 Bluetooth reading devices scattered throughout the city
- Access historical traffic and signal timing data archived by the TransSuite traffic control system

This center does not have staff specifically dedicated to its operation. It is predominantly used by city staff during special events and during major incidents to monitor and manage traffic on city streets.

5.1.5. COUNTY-HOSTED CENTRALIZED CONTROL FOR MONROVIA AMD DUARTE

In addition to the facilities described above, the cities of Monrovia and Duarte have each signed an agreement with LA County to have some of their signals operated by LA County's KITS traffic control system. In both cases, the signal control software will be run from LA County's TMC, but each city will remain in control of the operation of their signals through a remote KITS workstation installed in city offices.

5.2. TRAFFIC MONITORING SYSTEMS

This section provides a summary of systems that have been deployed along the I-210 corridor to monitor traffic demand and roadway conditions. These systems include:

- Freeway traffic detectors
- Arterial traffic detectors
- Closed-circuit television (CCTV) cameras
- Pasadena SMART Signal System
- Performance Measurement System (PeMS)

5.2.1. FREEWAY TRAFFIC SENSING

Caltrans currently maintain an extensive network of traffic detectors on freeways. The following summarizes deployed field elements within the I-210 corridor:

- **Freeway mainline detectors** – Figure 5-4 maps the mainline detection stations maintained by Caltrans on I-210 and surrounding freeway. Along I-210, 42 detection stations are maintained between the SR-134 and Foothill Boulevard interchanges in the eastbound direction and 46 stations in the westbound direction. In each direction, about half of the detectors are located west of the I-605 interchange and half on the east. As illustrated in Figure 5-5, mainline detection stations are typically located just upstream of an on-ramp. Spacing between successive mainline detection stations varies between 300 feet to 1.3 mile, with an average of 0.5 mile. Since single-loop, in-pavement detectors are used at all stations, each detection station only directly measures vehicle counts and loop occupancy. While speed measurements are outputted as well, these measurements are derived from the vehicle counts and loop occupancy data.
- **HOV lane detectors –** In each direction, traffic detectors are deployed along the existing HOV lane at the same locations as along the freeway mainline. Similar to the mainline detectors, these devices are used to obtain vehicle counts, loop occupancy data, and vehicle speed estimates.
- **On-ramp detectors** – All on-ramps along I-210 are equipped with traffic detectors. As shown in Figure 5-5, four types of detectors are typically used to monitor traffic on each on-ramp. At the downstream end of each ramp, a sensor is first installed on each traffic lane entering the freeway

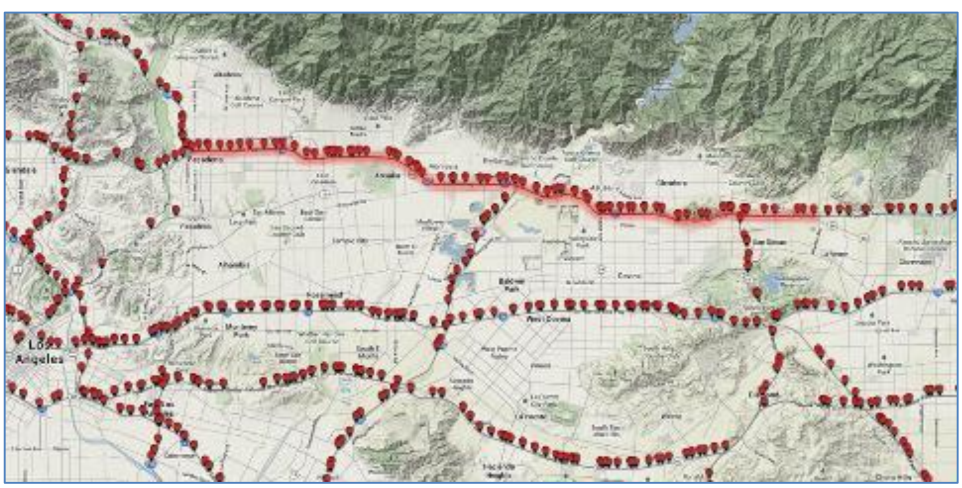


Figure 5-4 – Caltrans Mainline Freeway Traffic Detection Stations

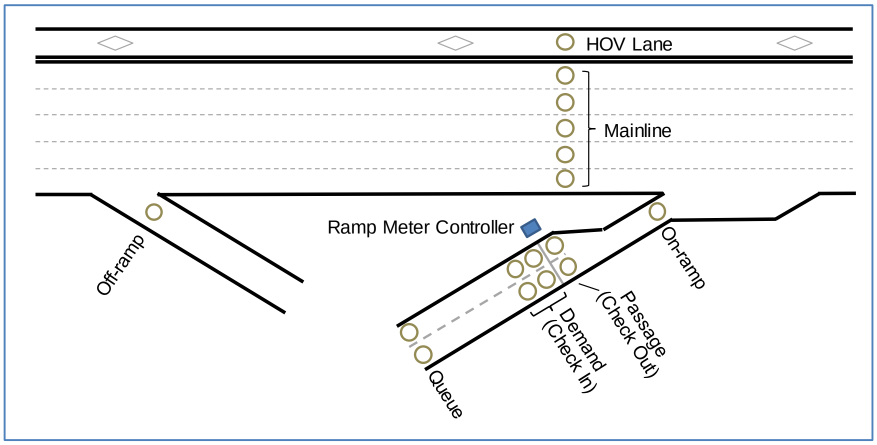


Figure 5-5 – Typical Sensor Layout along Freeways

mainline to count the number of vehicles entering the facility. Since these are typically single-loop detectors, they only provide vehicle counts and loop occupancy information. Vehicle speeds are not estimated. Near the metering stop line, demand and passage detectors are used to support ramp-metering operations. The demand detectors are used to detect the presence of a vehicle upstream of the stop line and call for a green signal, while the passage detectors are used to return the signal to red. Finally, at the upstream end of the ramp, a single-loop detector is typically installed to detect queues of vehicles threatening to spill onto the nearby surface streets.

- **Off-ramp detectors** – Most of the off-ramps along I-210 are equipped with traffic detectors. These are typically single-loops providing vehicle flow and loop occupancy data. They are primarily used to count the number of vehicles taking the ramps. The collected occupancy data may also be used to assess traffic conditions on the ramps. However, since the detectors are not currently linked to the traffic signals that may control traffic at the bottom of a ramp, the information they provide cannot currently be used to manage queues of vehicles that may threaten to spill onto the freeway mainline. Similar to the on-ramps, vehicle speeds are not estimated for these detectors.

5.2.2. ARTERIAL TRAFFIC SENSING

To support vehicle-actuated functionalities, most signalized intersections have traffic detectors installed on some or all of their approaches. Figure 5-6 identifies the intersections for which traffic detectors are known to be present, and the type of technology used for detecting vehicles. At a majority of intersections, traditional inductive loop detectors place within the pavement are used to sense traffic. However, a growing number of intersections are being equipped with video detection systems.

Depending on the location, one or two of the following types of detectors may be present on the intersection approaches:

- **Stop line detectors** – Detectors used to sense the presence of vehicles near the intersection stop line. Use of these detectors depends on their operational setting. When set in the "presence" mode, these detectors are used to place calls to the signal controller for the display of a specific green phase whenever a vehicle is in the zone of detectors. When set in "passage" or "gap" time, they are used to monitor the interval between successive vehicles and to determine when to terminate an active green phase.

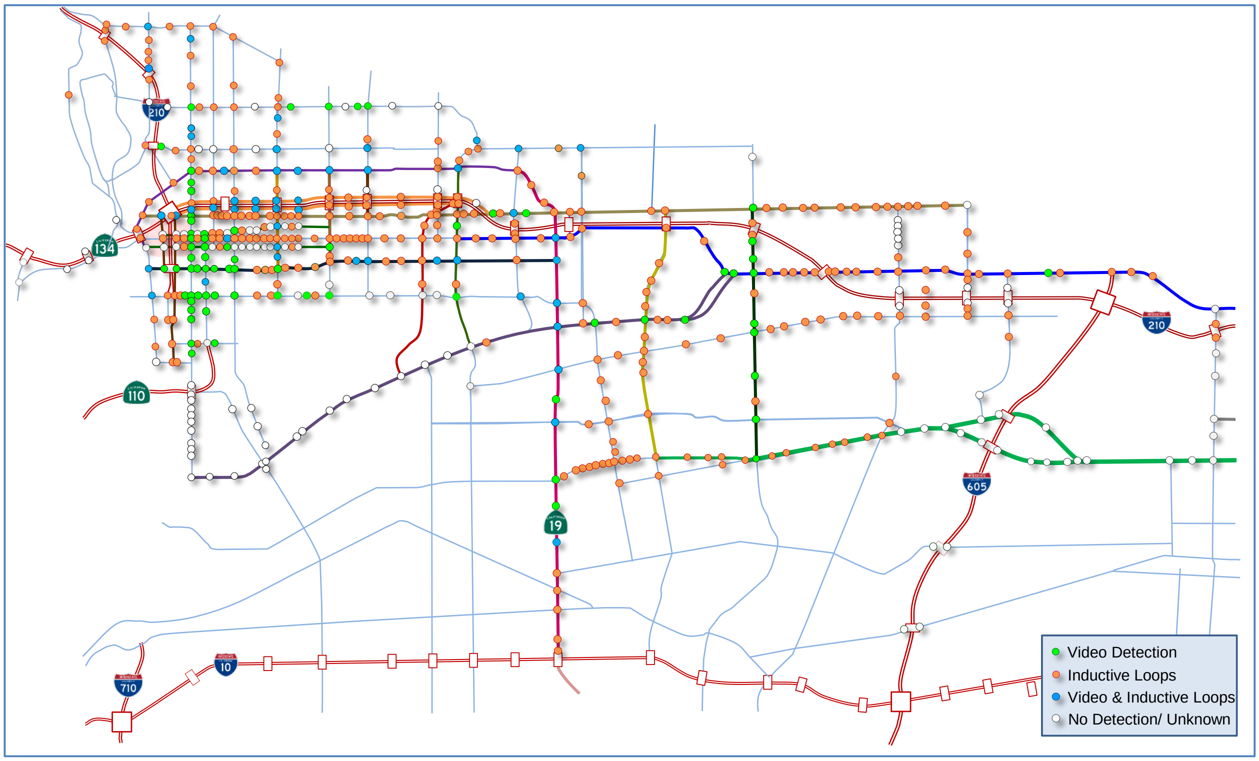


Figure 5-6 – Traffic Detection Technologies used by Jurisdictions West of I-605

- **Advanced passage detectors** – Detectors located some distance upstream of the stop line to sense vehicles approaching an intersection. These detectors are typically placed at a distance of three to five seconds behind the stop line and are used in actuated systems to place calls for an extension of the green signal each time a new vehicle is sensed to pass through the detection zone.

Figure 5-7 provides several examples of detector placements. The most frequent combinations is the one featuring advanced detectors on all approach lanes and stop line detectors on exclusive left turn and right-turn lanes (Example 3). This configuration allows monitoring the total traffic demand placed on an intersection and the proportion of left-turning vehicle within the total demand. However, it does not allow distinguishing right-turning vehicles from the through traffic. Depending on the approach, variance in the placement of the advance detectors may also result in some detection leaks. This may be the case where advanced detectors are placed downstream of the start of a left-turn or right-turn bay, as shown in Example 4 as such a placement may allow vehicles to pass besides the detectors.

While most intersections are equipped with detectors, the availability of sensor data to conduct operational analyses depends on whether the generated data is forwarded to a central location. Depending on the system setup, individual detectors may be defined as local or system detectors. Local detectors strictly send their data to the local signal controller, whereas system detectors are also set to send information to a central traffic control system. In the former case, the collected data is typically dumped by the signal controller after use. In the latter, data may be available for retrieval from a central database. Figure 5-8 summarily identifies the extent of traffic flow information that may be available from a central location for each intersection within the corridor. For each intersection, the figure identifies whether information is currently obtained from all approaches, some approaches, or no approach at all.

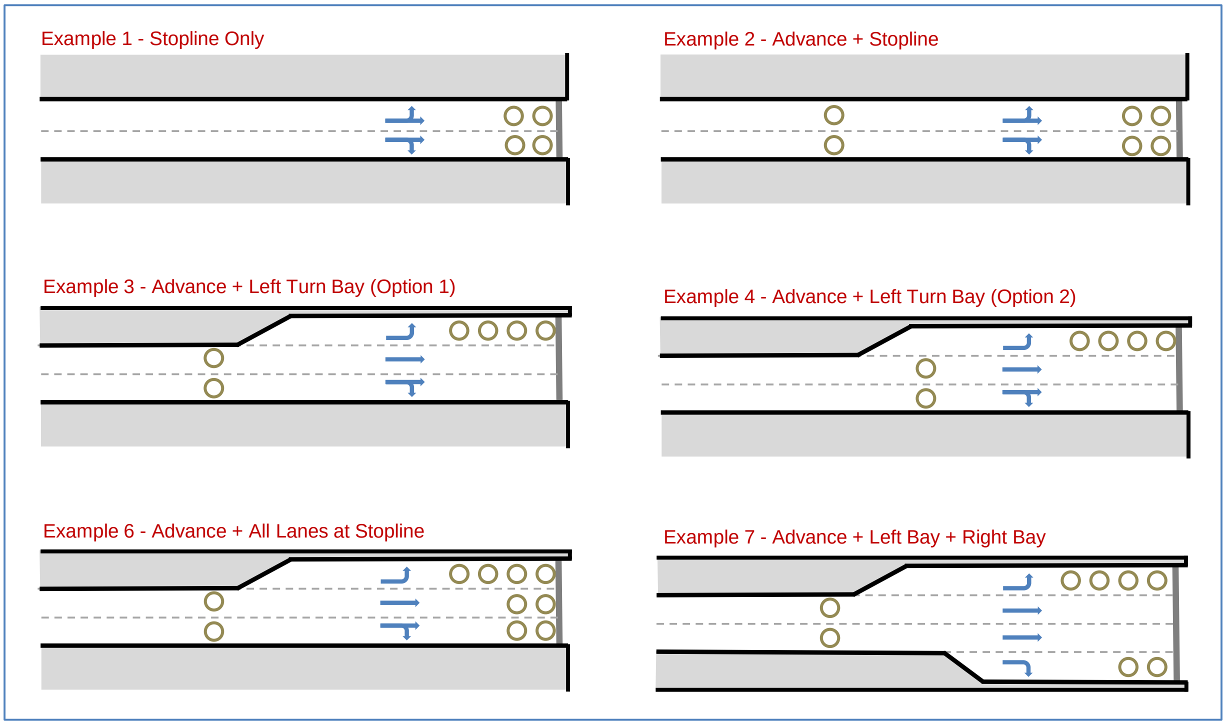


Figure 5-7 – Examples of Intersection Approach Detector Layouts

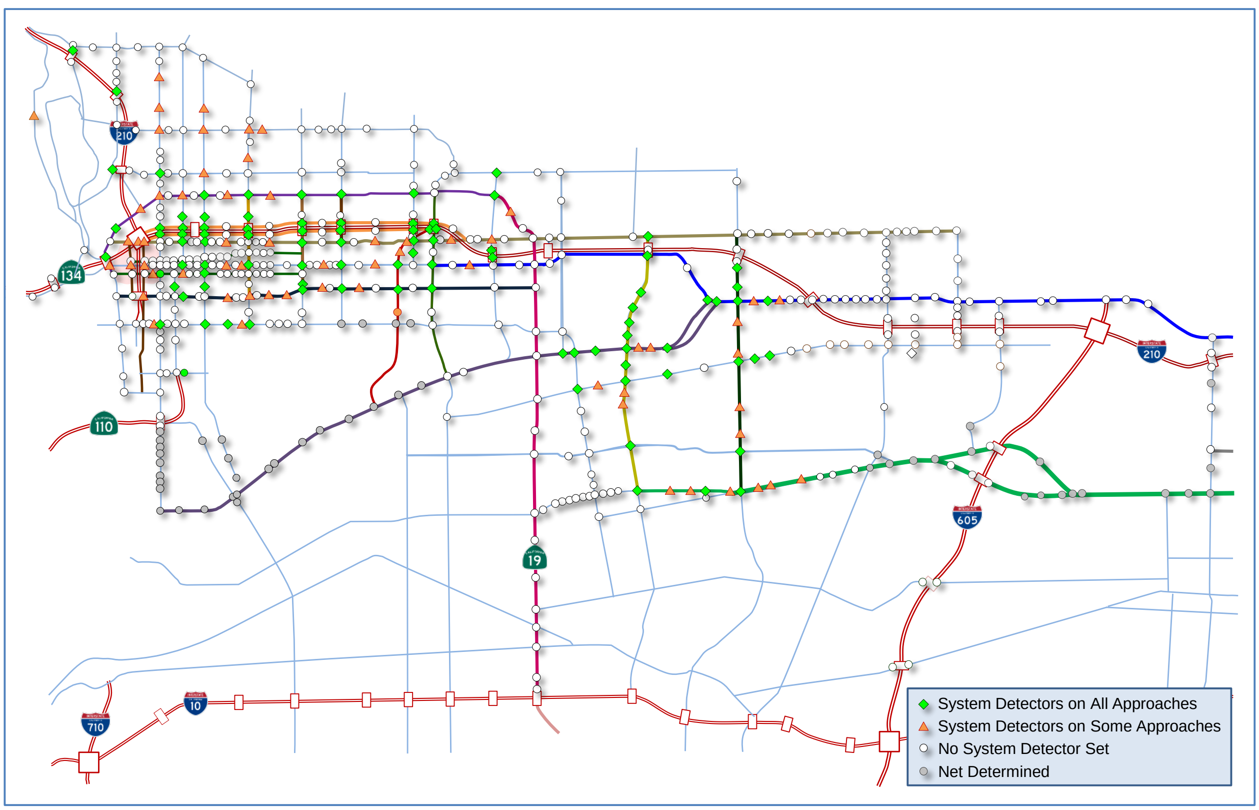


Figure 5-8 – Monitoring of Intersection Approach Volumes

The following provides a summary of the traffic flow data currently being collected by each agency:

- **Caltrans** – Caltrans-operated intersections typically have detectors on most of their approaches to support actuated signal control. This includes both advanced and stop line detectors. Unfortunately, the information collected by these detectors is not currently forwarded to the regional TMC. However, an exception exists for Caltrans intersections operated by the City of Pasadena. Historical data for these intersections may be available through the TransCore Series 2000 and McCain QuicNet Pro Traffic Control Systems. While a TranSuite traffic control system is currently being procured to support uniform statewide traffic signal operations, there is uncertainty as to when the intersections within the I-210 corridor will be connected to the system to be installed at the LARTMC.
- **Los Angeles County Department of Public Works** – While most of the intersections along arterials of interest are equipped with traffic detectors, the generated detector data is not currently forward to the KITS system. The data is strictly used in a local control capacity.
- **City of Pasadena** – 271 of the 323 signalized intersections within the city boundaries have some type of vehicle detection. Of these intersections, 84 are currently set up with system detectors capable of measuring volumes and speeds on some or all the approaches. Only data generated by intersections connected to the i2tms traffic signal control system are currently archived. Fifteen-minute aggregated data is retrieved once a day during the night. While there are plans to develop real-time data feeds, these have not yet been completed. In addition to the data provided by the i2tms system, traffic flow data may also be retrieved from the recently installed real-time SCATS traffic signal control system. Intersections equipped with a video detection system also generate cycle-by-cycle data. However, this data can only be retrieved by physically connecting a data collection device directly to the signal controller.
- **City of Arcadia** – Most of the 51 signalized intersections operated by the city are equipped with traffic detectors. The city's TranSuite traffic signal control system further provides real-time 5-minute traffic count data for 46 of the 51 intersections. Depending on the location, data may be provided from all installed detectors or from specific detectors on specific approaches.
- **City of Monrovia** – Most of the intersections along arterials of interest within the city are equipped with traffic detectors. However, generated detector data is not currently forwarded to a central location. The data is strictly used in a local control capacity.
- **City of Duarte** – Most of the intersections along arterials of interest within Duarte are equipped with traffic detectors. However, generated detector data is not currently forwarded to a central location. The data is strictly used in a local control capacity.

5.2.3. TRAVEL TIME MONITORING SYSTEMS

Two agencies within the I-210 corridor have installed Bluetooth devices to measure travel times between specific points within their local road networks. Figure 5-9 maps the location of the devices operated by the cities of Pasadena and Arcadia. More information about these devices is provided below.

- **City of Pasadena –** As part of a pilot project, Bluetooth devices have been installed in the Linda Vista Annandale neighborhood to track travel times and travel patterns on roads servicing the Rose Bowl during events. The locations of these devices are shown in the upper left corner of Figure 5-9.

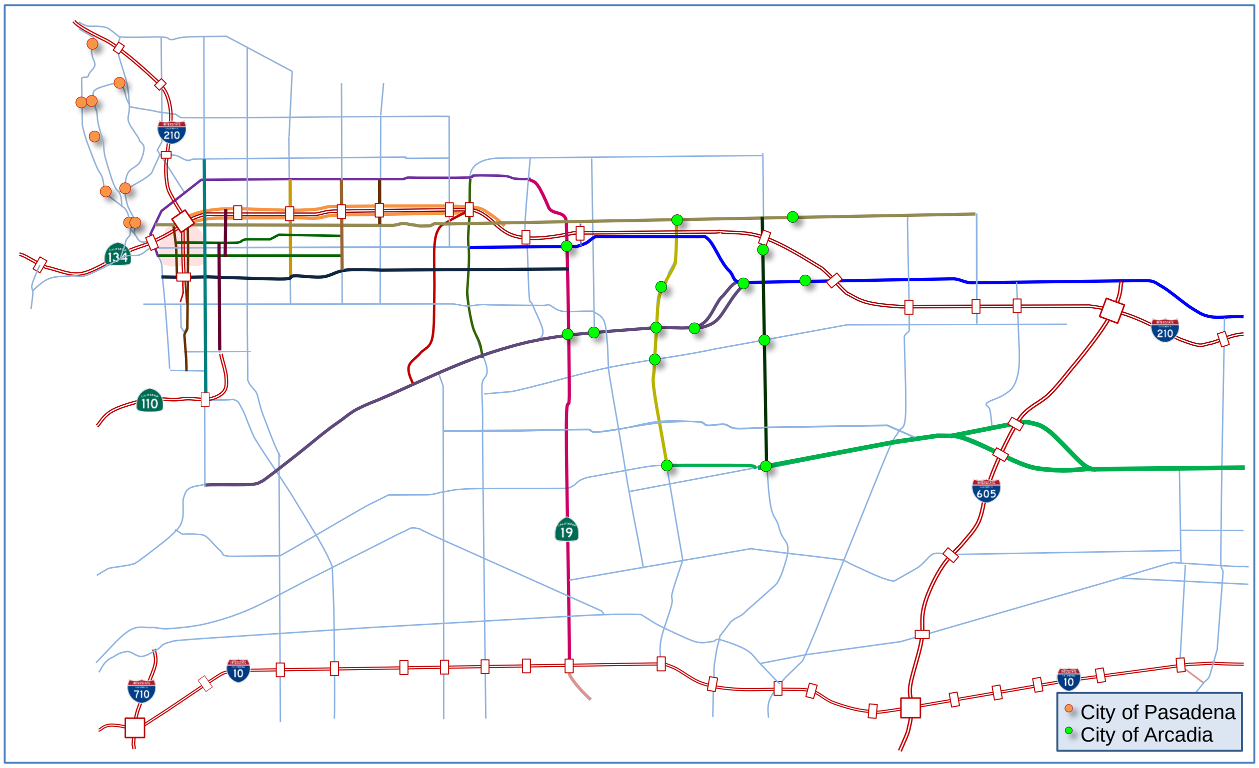


Figure 5-9 – Bluetooth Devices Operated by the Local Jurisdictions West of I-605

- **City of Arcadia –** 13 permanent Bluetooth detection stations were installed at strategic intersections in 2012 to help monitor travel times and travel patterns within the city's road network. With the help of LA County, two additional detectors were further installed in early 2014 along Rosemead Boulevard. Deployment of these detectors typically involved installing field-processing units in existing traffic signal cabinets and establishing Ethernet communication lines with a host data processing software residing on a city-owned server. No additional communication infrastructure or poles were required. This system currently supplies raw detection pings and observed travel times between detection stations each minute.

5.2.4. PASADENA SMART SIGNAL SYSTEM

In May 2011, the City of Pasadena implemented an experimental arterial traffic monitoring system developed at the University of Minnesota known as SMART (System Monitoring of Arterial Road Traffic) along Orange Grove Boulevard. This system, implemented at six signalized intersections between Lake Avenue and Sierra Madre Boulevard, collects traffic data from traffic sensor and traffic signal controllers to help traffic engineers monitor, evaluate, forecast and optimize arterial traffic flows. More specifically, it is designed to generate real-time intersection queue length and arterial travel time estimates using collected traffic flow and signal operation data, including all vehicle actuation calls. Queue lengths are predicted using traffic shockwave concepts, which allow queue estimates to be produced when queues of vehicles extends beyond the farthest upstream detector. Travel times are further estimated by simulating the movements of virtual probe vehicles along the monitored arterial.

5.2.5. CLOSED-CIRCUIT TELEVISION (CCTV) CAMERAS

Figure 5-10 maps the CCTV cameras currently operated by Caltrans and local jurisdictions along the I-210 corridor. More information about the cameras operated by each agency is provided below:

- **Caltrans** – Caltrans currently controls 18 CCTV cameras within the section of interest of the I-210 corridor. Figure 5-10 distinguishes two types of cameras: 7 cameras with video feed accessible on public website or by information service providers, primarily located near major interchanges, and 11 cameras set up for exclusive used by Caltrans staff.
- **LA County –** The Los Angeles County Department of Public Works has been operating a CCTV camera at the intersection of Huntington and Rosemead. In addition to this site, the County operates five other cameras within the San Gabriel Valley, mostly in the eastern portion of the valley.
- **City of Pasadena** – The City of Pasadena currently operates 30 CCTV cameras. However, plans have been approved to install at least 10 additional cameras.
- **City of Arcadia** – The city of Arcadia operates 18 CCTV camera arterials. Twelve of these cameras provide a digital video feed, while the remaining six provide an analog signal.
- **City of Monrovia** – The city of Monrovia currently operates 2 CCTV cameras along Huntington Drive, one at the intersection of 5th Avenue and the other at the intersection with Mayflower

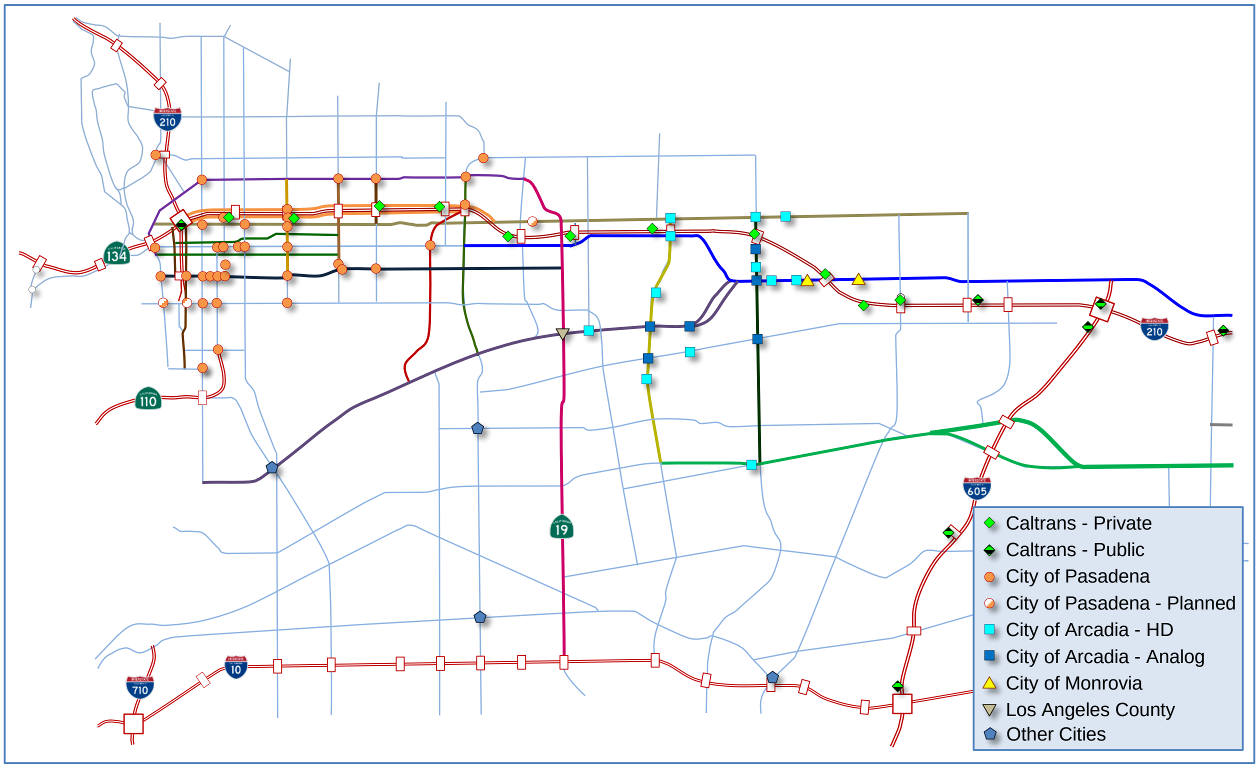


Figure 5-10 – Freeway and Arterial CCTV Cameras

5.2.6. PERFORMANCE MEASUREMENT SYSTEM (PEMS)

The Freeway Performance Measurement System (PeMS) is a web-based tool that was initially developed by Caltrans and the University of California to retrieve, process, analyze and store data collected by traffic monitoring systems. This system is now jointly maintained by Caltrans Headquarters and Iteris, with Caltrans Headquarters responsible for the maintenance of the system hardware and Iteris responsible for software maintenance and upgrades.

A PeMS screenshot is shown in Figure 5-11. In operation since 1999, the system currently allows users to retrieve and analyze data from the following sources:

- Traffic detectors operated by Caltrans on freeway mainlines and ramps
- Caltrans' Lane Closure System
- Caltrans freeway CMSs
- Incident reports logged by the CHP
- Accident records contained in the Traffic Accident Surveillance and Analysis System (TASAS)

In addition to providing access to real-time traffic sensor data, PeMS provides access to over ten years of historical data. The data analysis tools within PeMS further allow users to perform a wide range of investigations related to freeway operations. Among other things, the system may be used to retrieve information about the quality of data collected from traffic detectors; compile performance measures such as vehicle-miles traveled or delays for specific roadway segments, geographical areas, or periods; or develop regional aggregated traffic performance trends.

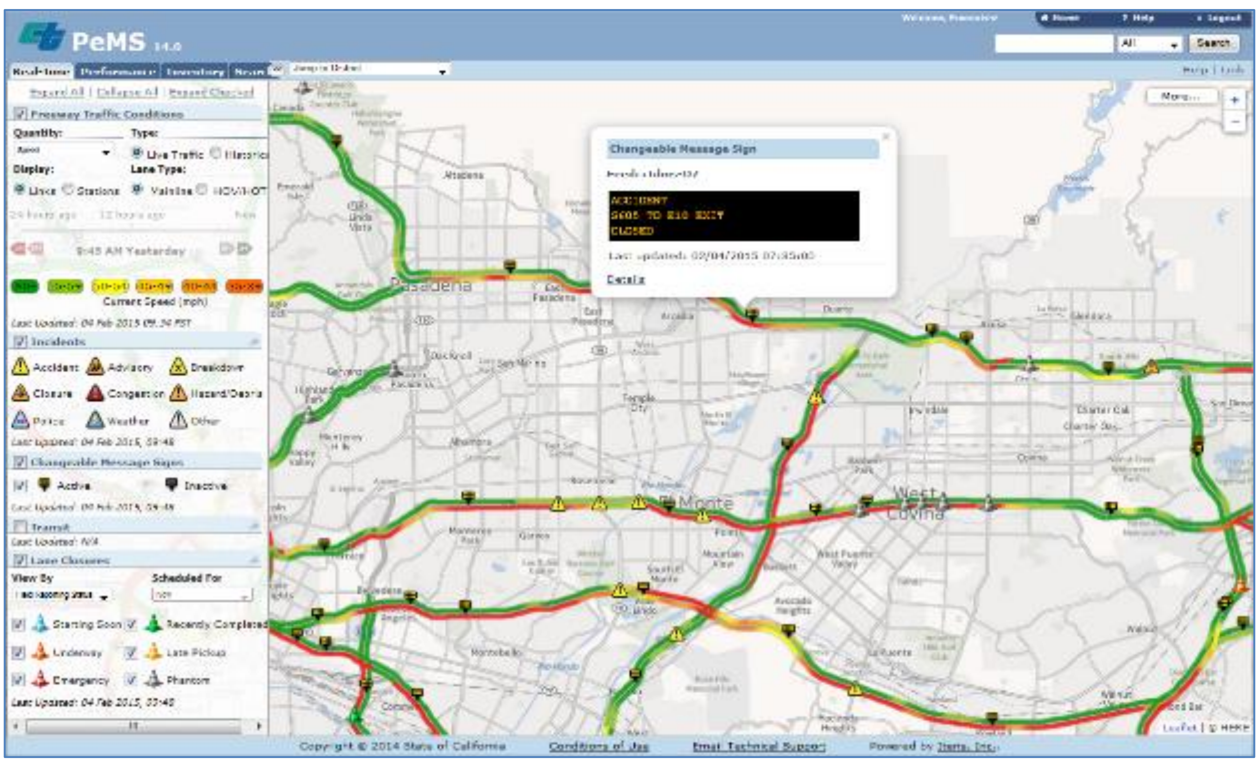


Figure 5-11 – PeMS Information System

5.3. FREEWAY RAMP METERING

Ramp metering uses traffic signals at freeway entrances and freeway-to-freeway connectors to regulate the volume of traffic entering a freeway, as well as the spacing between entering vehicles. From an operational standpoint, ramp-metering systems typically attempt to ensure that the total traffic entering a freeway segment remains below its capacity. A long operational history has demonstrated that ramp metering has the potential to prevent freeway congestion, or at least delay its onset and reduce its severity, by eliminating problems associated with the entry of large groups of vehicles at freeway on-ramps. The result is increased freeway throughput, increased operating speeds, reduced delays and improved overall operations. Ramp metering also initiates smoother and safer merging operations, which, in turn, improves safety by reducing rear-end and sideswipe collisions.

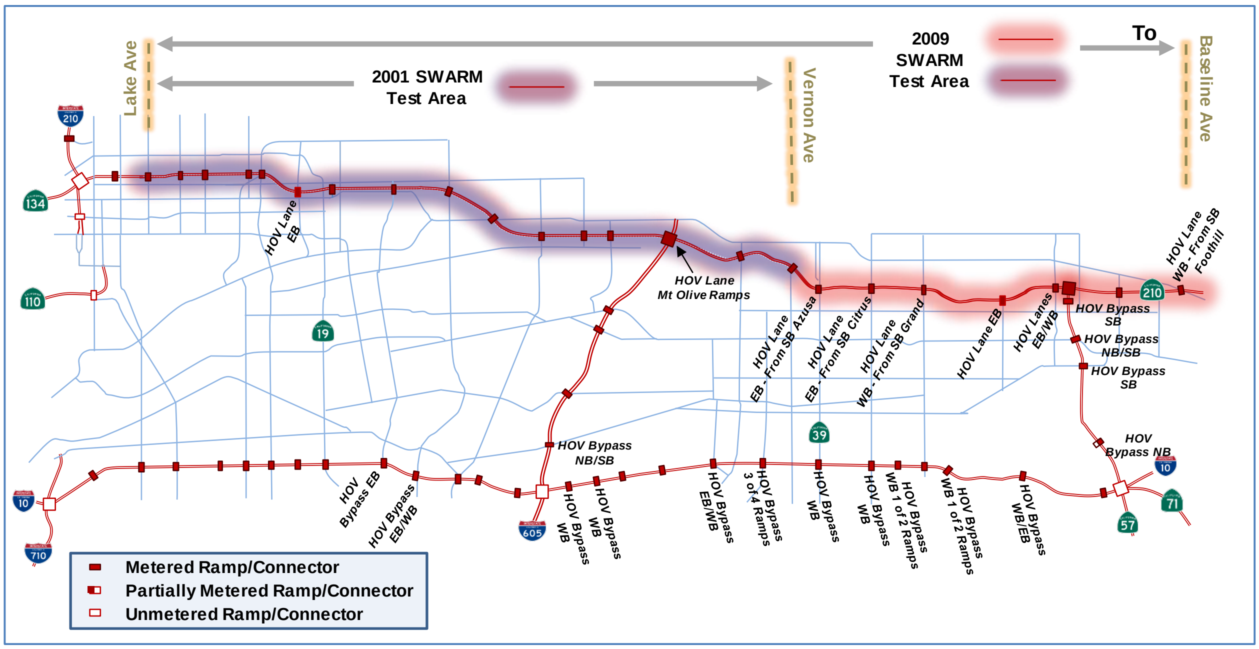


Figure 5-12 – Deployed Ramp Meters

605 and SR-57 freeways, where metering started in March 2008. The only non-metered interchange is the SR-134/I-210 interchange in Pasadena. As further illustrated, most on-ramps along nearby freeways are also metered. This includes ramps on the I-10 freeway running parallel to I-210, as well as along the sections of the I-605 and SR-57 freeways connecting I-10 to the I-210, with the exception of the freeway connectors at the I-10/I-605 and I-10/SR-57 interchanges.

Several ramps along I-210, particularly in the westbound direction, are equipped with metered HOV lanes. An example is shown in Figure 5-13. These lanes allow vehicles with two or more passengers to queue separately from the general traffic at the metering lights. Unlike other locations, such as along the I-605, SR-57, and I-10 freeways, these lanes do not allow the HOV vehicles to bypass the ramp meters completely. Most of the metered HOV lanes on ramps along I-210 freeway were previously HOV bypass lanes that were converted as HOV metered lanes in 2008 as part of the I-210 Congestion Relief Project.

Figure 5-13 – Examples of HOV Bypass and HOV Metered Lanes on Freeway Ramps

Three primary types of ramp metering are currently deployed within Caltrans District 7:

- **Fixed-Time / Time-of-Day (TOD)** – This is the simplest form of ramp metering. Its primary purpose is to break up platoons of vehicles entering the freeway. The ramp meters are simply turned on and off at specific times during the day and the rates with which vehicles are allow to pass adjusted based on a preset schedule. Operational parameters are typically developed to reflect historical average traffic conditions. There is no adjustment to actual traffic conditions.

- **Local Mainline Responsive (LMR)** – This strategy sets the metering rate on each ramp proportional to traffic conditions reported by the mainline freeway detectors placed immediately upstream of the ramp. When the traffic volume or loop occupancy is above the preset thresholds, traffic on each on-ramp is metered according to a predetermined table indicating which metering rate (typically out of a set of 16 rates) to apply based on the prevailing mainline traffic conditions. If the volume and occupancy drop below the defined thresholds, the ramp meter controller is then provided with the authority to override the preset metering rates to allow more vehicles on the freeway, up to the point of turning the ramp meters to a constant green light.

- **System-Wide Adaptive Ramp Meter (SWARM)** – Strategy seeking to optimize traffic flow on the freeway by responding to actual and forecasted traffic conditions. This strategy is actually comprised of three separate algorithms: SWARM-1, SWARM-2a and SWARM 2b. The SWARM-1 algorithm is based on the principles illustrated in Figure 5-14. At the start of each control interval, recent traffic flow information is used to identify the location of bottlenecks along the freeway and to forecasts traffic density at the bottlenecks over the next 7 to 10 minutes. Metering rates

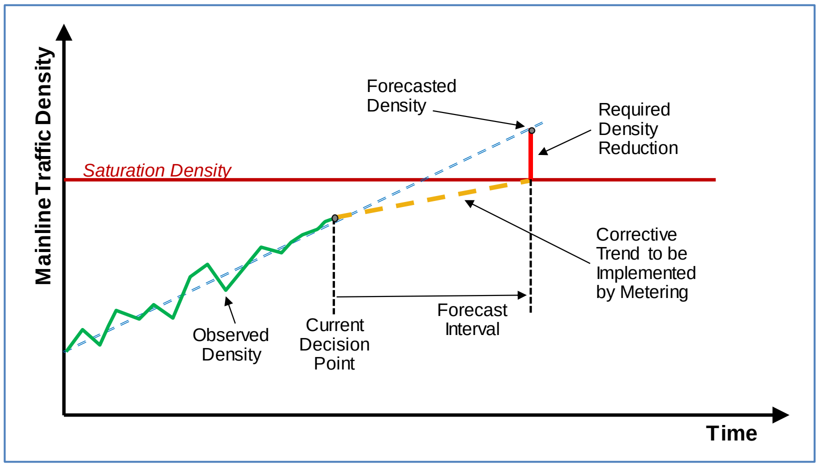


Figure 5-14 – SWARM Control Objective

at individual ramps between each pair of bottlenecks are then set to try to maintain the flow density at the downstream bottleneck below a given threshold. Calculations also take into account congestion that may propagate from downstream freeway sections where metering constraints may still allow more vehicle to enter the freeway than desired. The SWARM-2a and 2b algorithms focus instead on traffic conditions around each on-ramp. SWARM-2a determines the metering rate at each ramp needed to attain an ideal headway between vehicles that would maximize flow rate, while SWARM-2b tries to maintain a level of service D or better as long as possible by considering the number of vehicles that can be stored between two successive mainline detection stations. At the end of the calculations, the more restrictive metering rate from the three algorithms is applied, subject to minimum and maximum metering constraints.

Ramp meters along I-210 currently use the Local Mainline Responsive (LMR) algorithm. Fixed-time or simple Time-of-Day control is not normally used due to its insensitivity to traffic conditions. These approaches are only used when mainline detectors are down or during construction. While SWARM has been implemented along the corridor and field-tested twice, first in 2001 and again in 2008/2009, it is not currently used. While both tests have indicated that SWARM could effectively manage traffic, the obtained benefits were deemed not sufficient to justify replacing the existing LMR strategy.

Where a single car is allowed to pass per green signal, the ramp meters can be programmed to allow between 180 and 900 vehicles/hour/lane. Where two or three vehicles are allowed per green (platoon metering), between 600 and 1320 vehicles/hour/lane can be allowed to enter the freeway. On ramps equipped with queue detectors at their entrance, the ramp meter is further normally programmed to automatically increase the metering rate to the maximum rate possible (900 or 1320 vehicles/hour/lane) when stopped vehicles are present over the queue detector in order to prevent the ramp queues from spilling onto the nearby streets.

5.4. ARTERIAL TRAFFIC MANAGEMENT SYSTEMS

Figure 5-15 maps the location and operational ownership of the signalized intersections along key arterials within the I-210 corridor. Few stop-controlled intersections are also mapped to help assess constraints to traffic management options. The map indicates a relatively high density of signalized intersections (10 to 12 signals per mile) around downtown Pasadena at the western end of the corridor, medium densities on arterials running east of Pasadena and west of the I-605 freeway, and the lowest densities on arterial running east of the I-605 freeway. Throughout the corridor, local clusters of signalized intersections are further found near the historical downtown of various cities or significant commercial areas.

To understand fully the operational context of the I-210, it is not sufficient to know simply where traffic signals are located. It is equally important to understand how these signals are operated and what the capabilities are. To answer these questions, the following aspects of traffic signal control are discussed in more details in the subsections that follow:

- Types of traffic signal control
- Signal synchronization groups
- Types of signal control equipment used
- Traffic detection support
- Centralized control capabilities

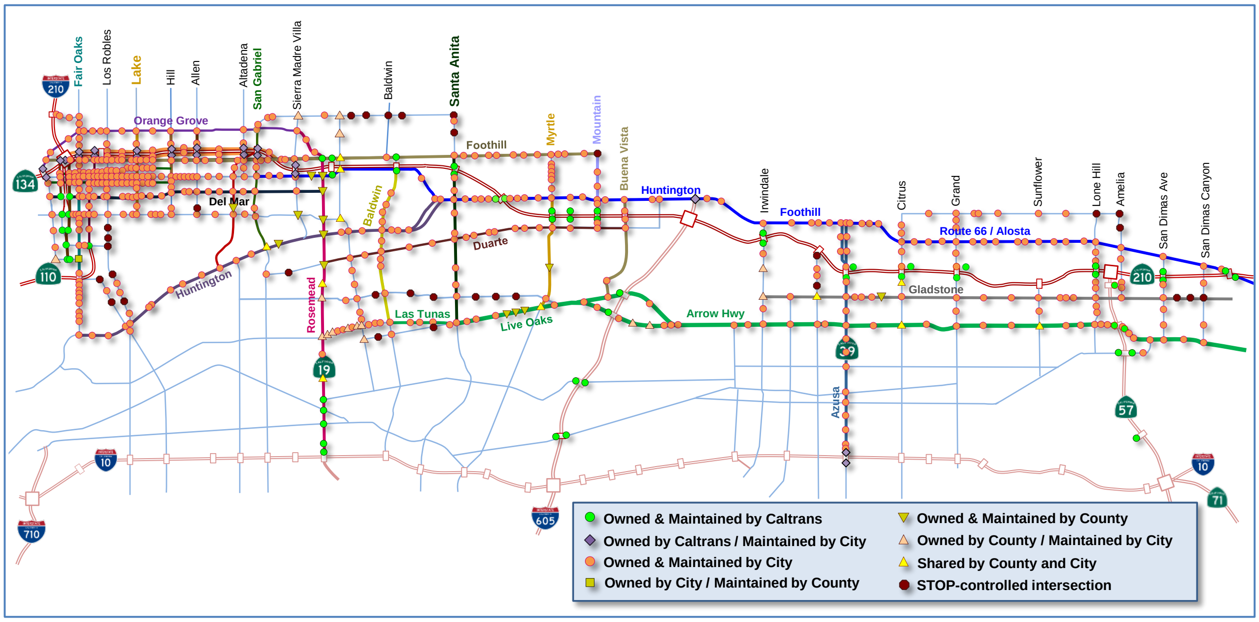


Figure 5-15 – Intersection Control along Key Arterials

5.4.1. TYPE OF TRAFFIC SIGNAL CONTROL

Depending on the location, time of day and operating agency, individual traffic signals within the I-210 corridor may be operated according to one or more of the following modes:

- **Fixed-time or pre-time control** – Mode of operation in which the signals cycle through the green, yellow and red indications following a predetermined sequence, without adjustment of the duration of each signal indication to the actual traffic demand in each cycle. Average historical traffic conditions are typically used to determine each signal duration.
- **Fully actuated control** – Control using vehicle detections to trigger the display or determine the duration of specific phases. In this case, all approaches to an intersection are typically equipped with traffic detectors, either at the stop line, at some distance upstream from the stop line to provide detection 3 to 5 seconds before arrival, or at both the stop line and upstream location. The green signal is passed from one movement to next based on received detection calls, subject to maximum green constraints. Since phases without demand can be skipped, the phase sequence and phase duration can be entirely determined by the traffic demand.
- **Semi-actuated control** – Type of actuated control using vehicle detection only for the minor movements. In typical setups, detectors may only be installed on the minor cross street and left-turn bays along the major street. The green signal is then programmed to dwell on the main traffic movement and is only transferred to a minor movement after a call for service is received. This again results in an operation in which the cycle length is variable.
- **Coordinated-actuated control** - Variation of semi-actuated control in which a fixed cycle and a coordination reference point (offset) is imposed on the signal operation to promote synchronized operation with adjacent intersections. Similar to semi-actuated control, the duration of phases serving minor traffic movements is based on detection calls received. However, any unused green within the allotted time to minor phases is in this case transferred to the main phase.

- **Traffic-responsive control** – Mode of operation in which the fixed-time plans to implement within a control period is determined based on traffic flow data collected from traffic detectors. Plan selection may be based on measured traffic volumes, observed traffic speeds, the directional distribution of traffic, time of day, special detection, and/or other inputs.
- **Traffic adaptive / real-time control** – Mode of operation within which the signal timing parameters are adjusted every cycle or every few minutes to match the observed traffic demand. Predefined timing plans are not necessarily used. The signal timings continuously evolve with observed changes in traffic conditions.

Along the corridor, coordinated-actuated is the dominant mode of operation during peak periods. Most of the intersections along major arterials are equipped with detectors allowing the signal controllers to adjust the duration of each phase to the actual traffic demand. During periods of low demand, the signals typically cycle through a set of phases without any defined cycle length. However, to enable synchronized operations with other signals, a specific cycle and offset is typically imposed at key intersections during peak periods. Only a few intersections may still operate in a fully actuated mode during this period.

Adaptive systems are currently used, or planned to be used, at a very small number of intersections along the corridor. Systems currently in operation or under development include:

- **Fair Oaks SCATS Corridor** – A SCAT real-time control system has recently been implemented by the City of Pasadena along a 12-intersection segment along Fair Oaks Avenue between the I-210 and SR-110 freeways. This system has been implemented to resolve traffic problems created by frequent signal preemption along the Metro Gold Line and to better handle the frequent surges of traffic that occur along this arterial. It uses stop line detectors to monitor how each green signal is used and to determine which of the predefined control plan contained in a library should be used to manage traffic along the arterial, as well as what local, temporary modifications could be made to the selected plan at each intersection to improve local operations.
- **Pasadena Light-Rail At-Grade Crossing System** – Several intersections along Metro's Gold light-rail line have been equipped with a treatment implementing a flashing yellow to allow to reduce the amount of preemption needed to clear roadways prior to the passage of a train.
- **Arcadia Adaptive Signal Control System** – The City of Arcadia is currently working with KLD Associated to implement an adaptive traffic signal control system along some of the city arterials. This system will enable the signal timing parameters at intersections controlled by the system to be updated as quickly every 30 minutes based on detected traffic conditions.

5.4.2. MULTI-INTERSECTION SIGNAL SYNCHRONIZATION

To facilitate smooth progression across successive intersections, groups of signals along arterials often have their operation synchronized. This practice typically results in the imposition of a common cycle length to all intersections in the group, and in the establishment of fixed time points, or offsets, at which a reference phase must start at each intersection.

Figure 5-16 maps the arterial segments that have been synchronized through LA County's Traffic Signal Synchronization Program since 1988 or for which synchronization is currently being planned. The map indicates several key arterials within the I-210 corridor that have already had their signals synchronized. In addition to the development of new signal timings, these projects have also installed new traffic detectors and upgraded traffic signal controllers where existing instrumentation was deemed insufficient.

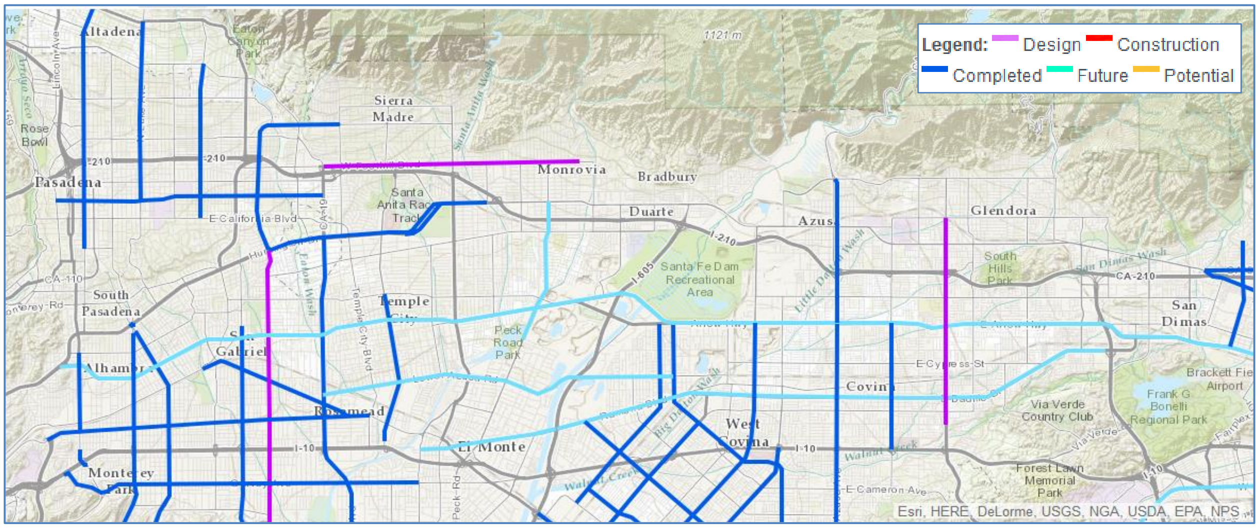


Figure 5-16 – Completed and Planned Traffic Signal Synchronization Projects from LA County

Not shown in Figure 5-16 are arterial segments that may have been coordinated by individual agencies within their jurisdiction. Information obtained from the City of Pasadena indicates, for instance, that 34 signal coordination groups are currently defined within the city. While some of these groups correspond to segments that were coordinated through the LA County programs, several others correspond to segments not shown in Figure 5-16. Several coordination groups also exist within the City of Arcadia, notably along Baldwin Avenue, Santa Anita Avenue, and Duarte Road.

While efforts have been devoted to coordinate traffic signals along key arterials, significant breaks in synchronization still exist, particularly around Caltrans-operated intersections. Except for the intersections along Maple Street, Corson Street and a few other locations within Pasadena for which control has been passed to the city, Caltrans typically operates its signals independently from nearby city-controlled signals. Since most of these are operated in a vehicle-actuated mode throughout the day, they may not always operate with the same cycle as nearby signals. However, while no formal synchronization may exist, some indirect synchronization may still result from the implementation of signal timings designed to accommodate the cyclic traffic patterns that are normally produced by the nearby signals.

5.4.3. SIGNAL CONTROLLERS

Figure 5-17 indicates that the dominant type of signal controllers used in the western half of the I-210 corridor is the Type 170. More advanced Type 2070 controllers are currently mostly found along Colorado Boulevard and Del Mar Boulevard in Pasadena, as well as various other isolated locations, typically where complex traffic patterns or control problems resulted in poor operation of Type 170 controllers.

While two types of controllers equip the vast majority of intersections, there is significantly more variation in the firmware used to operate the devices, as evidenced by the data of Table 5-1. Among these, the LACO firmware developed by the Los Angeles County Department of Public Works is the most common. This firmware equips controllers operated by Los Angeles County and the cities of Arcadia, Duarte, Monrovia and several other cities within the county. Proprietary software is also used by Caltrans to operate the intersections under its direct control. On the other hand, the City of Pasadena generally relies on firmware provided by commercial vendors. Use of commercial firmware has also recently been

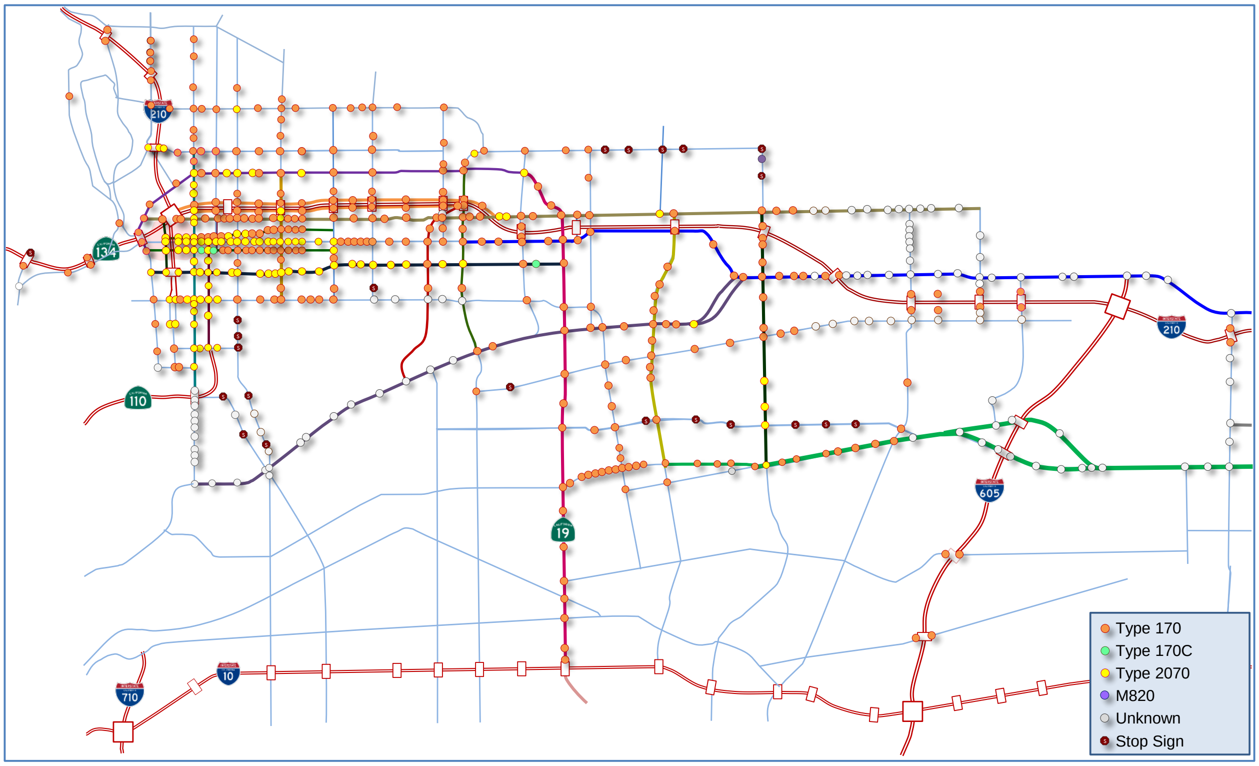


Figure 5-17 – Signal Controller Types in Use in Western Section of Corridor

Table 5-1 – Signal Controller Firmware in Use in Western Section of Corridor

Developer	Controller Type	Firmware	Versions	Users
Los Angeles County Department of Public Works	170	LACO	LACO-4 LACO-4E LACO-1R LACO-1H LACO-1HC	Los Angeles County, Arcadia, Monrovia, Duarte
Caltrans	170	C7 Program	--	Caltrans
		C8 Program	Version 3 (C8V3) Version 4 (C8V4)	Caltrans
	2070	TSCP	2.12	Caltrans
McCain	170	Program 222P	--	Pasadena
		Program 233	--	Pasadena
	2070	Program 2033	--	Pasadena
		Omni eX	--	Arcadia
Fourth Dimension Traffic	2070	D4	--	Arcadia
Road and Traffic Authority of New South Wales, Australia	2070	SCATS	--	Pasadena

favored by the City of Arcadia, which has started to replace some of its LACO-operated 170 controllers with 2070 controllers running on firmware provided by two vendors.

5.4.4. TRAFFIC DETECTION SUPPORT

To support vehicle-actuated functionalities, most signalized intersections have traffic detectors on some or all of their approaches. Signal operation may be supported by one or two of the following types:

- **Stop line detectors** – Detectors used to sense the presence of vehicles near the intersection stop line. Use of these detectors depends on their operational setting. When set in the "presence" mode, these detectors are used to place calls to the signal controller for the display of a specific green phase whenever a vehicle is in the zone of detectors. When set in "passage" or "gap" time, they are used to monitor the interval between successive vehicles and to determine when to terminate an active green phase.
- **Advanced passage detectors** – Detectors located some distance upstream from the stop line to sense approaching vehicles. These detectors are typically placed at a distance of three to five seconds behind the stop line and are used to place calls for green signal extension each time a new vehicle is sensed to pass through the detection zone.

Several examples of detector placements were provided in Figure 5-7. The most frequent combination for the I-210 corridor is the one in which intersection approaches are equipped with advanced detectors on all approach lanes and stop line detectors on exclusive left turn and right-turn lanes.

5.4.5. CENTRALIZED CONTROL AND MONITORING CAPABILITIES

Table 5-2 inventories the traffic management systems currently used by individual jurisdictions to control the traffic signals under their jurisdiction. Figure 5-18 further indicates for the western half of the corridor the system that each intersection uses. The following key observations can be made from the data:

- A variety of commercial traffic control systems are used to support traffic signal operations. Systems in operation currently include systems developed by Kimley-Horn (KITS), TransCore (TransSuite), McCain (QuicNet), Siemens (i2), Econolite (Centracs), and the Road and Traffic Authority of New South Wales in Australia (SCATS).
- Most of the systems currently in operation provide agencies with second-by-second signal status information and enable them to alter signal operations from a remote workstation.
- Not all systems are currently set up to forward traffic detection data to the associated TMC. Systems currently archiving traffic flow data include the TransSuite system used by Arcadia (data provided in real time at 5-minute intervals), the i2 system used by Pasadena (flow data downloaded once a day) and Pasadena's SCAT system (real-time flow data processing).
- The most commonly used control system within the I-210 corridor is KITS. This system was procured by LA County from Kimley-Horn in 2004 to operate signals in unincorporated county areas. Since then, signals within the cities of Temple City, San Gabriel, El Monte, Baldwin Park, and Covina have also been connected to the County KITS, while San Dimas has procured its own version of the system. It is anticipated that 10 signals within Monrovia and 5 within Duarte, mainly along Huntington Drive, will be connected by the end of January 2015. Future deployment is also being planned for signals within San Marino.

- In cities using KITS, the county system is typically only used as a host. While the signals are physically connected to the system installed in LA County's TMC in Alhambra, each city remains in charge of managing its signals. An exception is for the city of Temple City, where LA County has been tasked by agreement to manage and to operate the signals on behalf of each city. In these cases, the cities only retained the right to determine how their signals should be operated.
- While individual cities typically rely on a single traffic signal control system, Pasadena has relied for many years on four systems. Of the city's 341 signalized intersections, 215 have been supervised by a Siemens i2 system. This is a legacy system that the city is considering upgrading or replacing. A McCain QuicNet/Pro system supervises an additional 62 intersections, mostly at intersections near at-grade crossings along the Metro Gold Line light-rail and at intersections along planned bus rapid transit routes. Deployment of this system at these locations is based on its abilities to provide priority to light-rail vehicles and buses while attempting to sustain signal coordination along the crossing arterials. A TransCore Series 2000 system further controlled 35 intersections for which operation is shared with Caltrans or Los Angeles County. However, control of these intersections was migrated to the QuicNet system in December 2014. Finally, a SCAT real-time traffic signal system has recently been implemented at 12 intersections along Fair Oaks Avenue to address complex signal coordination and light-rail priority issues along that arterial.

Table 5-2 – Traffic Signal Control Systems

Jurisdiction	Kimley-Horn KITS	Siemens i2tms	McCain QuicNet Pro	Econolie Centracs	TransCore Series 2000	TransCore TransSuite	SCATS
Caltrans						●	
LA County	●						
Pasadena		●	●		● [3]		●
Arcadia						●	
Monrovia	Planned [1]						
Duarte	Planned [1]						
Irwindale						●	
Azusa	*System to be selected in the future*						
Glendora				●			
San Dimas	●						
La Verne				●			
Alhambra						●	
San Marino	Planned [1]						
San Gabriel	● [1]						
Temple City	● [2]						
El Monte	● [1]						
Baldwin Park	● [1]						
Covina	● [1]						
West Covina						●	

[1] Signal operations to be hosted by KITS at the Los Angeles County TMC, but management of signal timing plans to remain under local jurisdiction control

[2] Signals maintained and operated by the Los Angeles County Department of Public Works, with the city retaining control over signal operation

[3] Signals to be migrated to Siemens i2tms system by January 2015

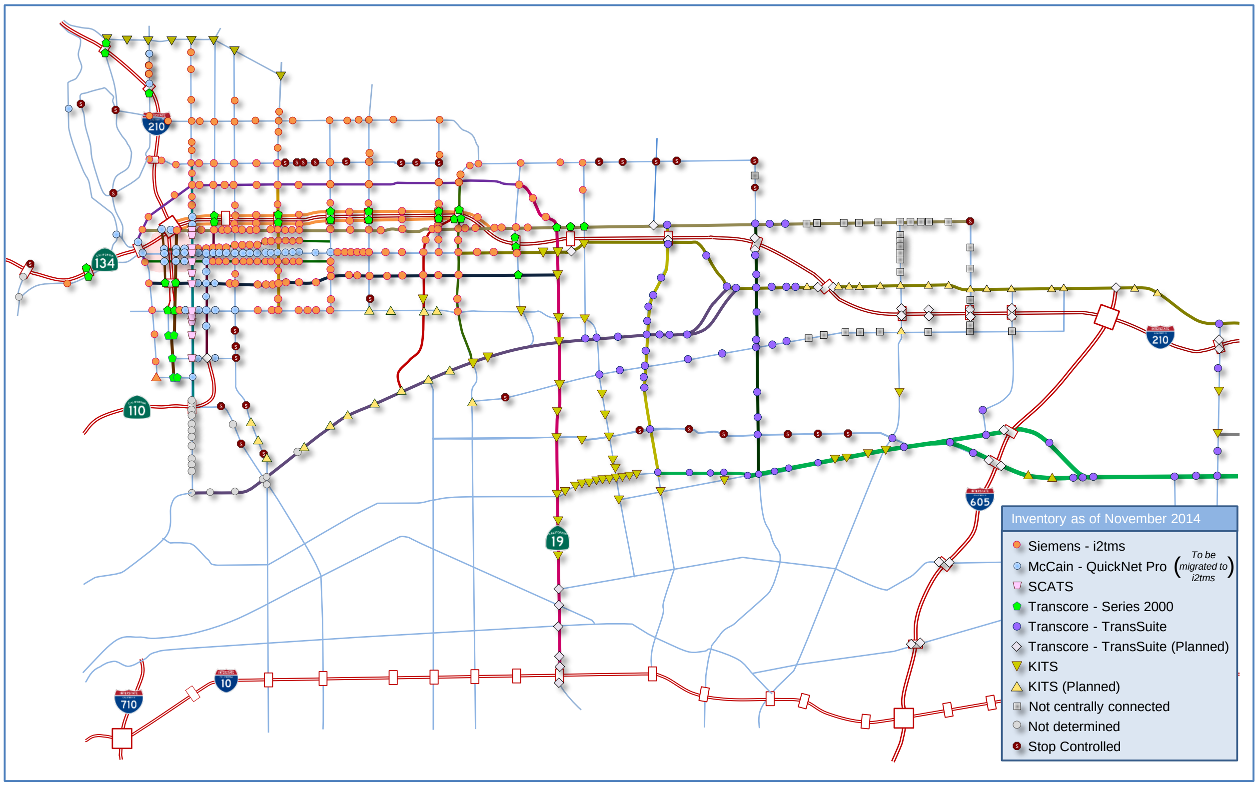


Figure 5-18 – Traffic Control System Deployments

- While Caltrans does not currently operate a centralized traffic signal control system, the agency has recently procured a TransSuite system from TransCore for the monitoring and management of at all traffic signals operated by the agency within California. While the system is currently operational at the LARTMC, it is still unknown when all Caltrans-operated intersections within the I-210 corridor will be connected to the centralized system.
- After installing a TransSuite system, Arcadia is currently working with KLD Associates to develop an add-on capability that will enable the system to adapt signal responses to actual traffic flows.

5.5. INCIDENT/EVENT MANAGEMENT SYSTEMS

Assets used to assist with the management of incidents and events within the I-210 corridor include:

- Caltrans Planned Lane Closures System
- CHP's Computer-Aided Dispatch (CAD) system
- Caltrans District 7 Event Management System
- Metro Freeway Service Patrol
- Caltrans Traffic Management Team

5.5.1. CALTRANS PLANNED LANE CLOSURE SYSTEM

Caltrans' Lane Closure System (LCS) allows Caltrans traffic managers to track lane, ramp, and road closures due to construction, maintenance, and encroachment permit activities. This statewide system tracks active closures as well as all planned closures for the next seven days from any given day. District TMCs can utilize this information to monitor both their own closures as well as those planned on highways in adjacent districts, as well as to coordinate closures with neighboring districts.

5.5.2. CALIFORNIA HIGHWAY PATROL'S COMPUTER-AIDED DISPATCH SYSTEM

CHP's Computer-Aided Dispatch (CAD) system is a secure system used by the CHP to support dispatch and response functions. It links all dispatcher workstations, provides reliable and accurate incident information, and both standardizes operational procedures and decreases incident response times by eliminating previously used manual processes. Although not a Caltrans system nor originally intended for Caltrans use, this system has become one of the primary methods for disseminating incident information within TMCs as it is often the point of first notification for an incident and because it provides regular updates as a situation progresses.

5.5.3. CALTRANS AUTOMATED INCIDENT DETECTION SYSTEM

In addition to accessing the CHP CAD system, Caltrans District 7 uses the All-Purpose Incident Detection (APID) algorithm to assist with the detection of incidents. This algorithm scans flow, speed and loop occupancy data collected from individual traffic detection stations to assess whether sudden changes in traffic conditions have occurred over time or whether unusual data patterns exist across successive stations. Alert messages are sent to TMC operators following the detection of unusual data patterns. Following the reception of an alert message, TMC operators are then responsible for assessing whether the observed changes in traffic conditions or unusual data patterns are due to the presence of an incident.

5.5.4. CALTRANS DISTRICT 7 EVENT MANAGEMENT SYSTEM

Another important element of the LARTMC is an event management system designed to provide operators with responses to incidents, emergency closures, and major scheduled events. This system, which was developed by Delcan, develops a standardized response plan for each incident by relying on information characterizing an incident, such as location, time, type, and number of vehicles involved, as well as rules formulated by experts in freeway management. Response plan elements include items such as which changeable message sign and highway advisory radios to use, which messages to post, whether operators should request a Sig Alert (incident notification) to be generated, who should be contacted regarding the incident, etc.

5.5.5. METRO FREEWAY SERVICE PATROL (FSP)

The Metro Freeway Service Patrol (FSP) is joint program provided by Metro, Caltrans, and the CHP. The FSP is a team of privately owned tow trucks that patrol designated routes on congested Los Angeles County freeways to provide help to stranded motorists and assist in clearing traffic accidents to keep traffic moving. Services by the FSP include changing flat tires, jump-starting dead batteries, refilling radiators and temporarily repairing leaking hoses, or providing a gallon of fuel. If the FSP cannot get a stranded car running within ten minutes, it will tow the vehicle to a safe location off the freeway. The FSP also assists emergency responders in clearing traffic accidents. The goal of the FSP is to maximize the effectiveness of the freeway transportation system by promptly removing disabled/stranded vehicles from the freeway.

This program typically operates Monday through Friday during peak commute hours, and all day in pre-designated freeway construction zones. In heavily congested freeway corridors, it is also becoming more commonplace for the FSP to operate during the midday and on weekends/holidays in addition to the weekday peak-period service.

Services are provided to motorists at no cost. State and local public funds allocations support the program. State funding is apportioned to each FSP program through a formula considering population, miles of freeway in the region, and congestion measurements. Local transportation agencies typically match the state funding allocation with a minimum of 25 percent of local funds.

5.5.6. TRAFFIC MANAGEMENT TEAMS (TMT)

The Traffic Management Team is a team of Caltrans employees that can be dispatched from various locations throughout the District at any time, day or night, to help alert motorists of emergency lane closure or unexpected freeway closures following incidents such as major injury, spilled cargo, or other natural disasters that may obstruct the roadway. Following an incident, it may dispatches portable truck-mounted changeable message signs to prevent secondary collisions, and provide delay information to motorists. The team may also perform traffic analyses and post detours as necessary.

5.6. TRANSIT MANAGEMENT SYSTEMS

This section provides a summary of the transit management systems currently deployed within the I-210 corridor. These systems include:

- Automated vehicle location (AVL) systems
- Automated passenger counting (APC) systems
- Transit signal priority (TSP) systems

5.6.1. AUTOMATED VEHICLE LOCATION (AVL) SYSTEMS

Several transit agencies within the I-210 corridor have deployed systems enabling them to track in real time or near real-time the location of individual transit vehicles. These systems are generally used by operators to aid dispatchers with identifying the location of vehicles, tracking route adherence, assessing performance, and facilitating the resolution of incidents. These systems are also increasingly being used to support the provision of real-time next arrival information to transit riders.

The following is a brief description of the AVL systems in operation within the corridor:

- **Metro Buses and Trains** – All buses and light-rail trains operated by Metro are equipped with a system allowing transit operators to track their position. This is a time-point based system. The position of each vehicle is not tracked centrally on a second-by-second basis but rather at periodic intervals. While a GPS link is used by the onboard equipment to track the position of a vehicle, the transit management center only obtains vehicle location data when the system communicates witch a vehicle via a radio link, typically once every 3 to 5 minutes.
- **Foothill Transit Buses** – As part of its SMARTBus System deployment in 2007, Foothill Transit equipped all its buses with a GPS-based vehicle location system. This system is similar to the one used by Metro. While onboard equipment continuously tracks the location of each vehicle

through a GPS link, the vehicle location is only forwarded to the transit management center when the AVL system establishes radio communication with the vehicle to retrieve the location data. The agency is currently seeking to replace this system with a newer system leveraging recent technological advances to provide added functionalities.

- **Pasadena Transit Buses** – As part of its proposed Transit Vehicle Arrival Information System, Pasadena Transit is currently planning the deployment of an AVL system capable of tracking buses every 20 seconds for its entire fleet of buses. This system should become operational in the very near future.

Other agencies can access the vehicle location data generated by Metro's and Foothill Transit's AVL systems through dedicated XML data feeds on the RIITS network. Access to this data is only available to public agencies involved in transportation and is subject to approval by the RIITS Administrator.

5.6.2. AUTOMATED PASSENGER COUNTING (APC) SYSTEMS

All Metro and Foothill Transit buses currently have automated passenger counting (APC) devices installed onboard the vehicles. These devices allow each agency to track the number of passengers boarding and alighting at each stop. This information is typically used to estimate ridership, assess route segment utilization, assess the level of utilization of individual service stops, etc. Sensing is typically done using infrared detectors mounted above a vehicle's doors. Whether passengers are boarding or alighting is determined by using detectors capable of determining direction of movement.

The following is a brief description of the APC systems in operation within the corridor:

- **Metro Buses** – All buses operated by Metro have automated passenger-counting devices installed onboard. Similar devices are not installed on light-rail train cars, mainly due to the difficulty of accurately counting the number of persons passing through the train's wide doors. Similar to the vehicle's location, information about the number of passengers present onboard a vehicle is not continuously sent back to the transit management center. Data is typically retrieved from the onboard system when a vehicle returns to its garage.
- **Foothill Transit Buses** – Foothill Transit buses typically have automated passenger-counting devices installed onboard each vehicle. The system used for counting passengers is similar to the one used by Metro.
- **Pasadena Transit Buses** – Pasadena Transit buses are not currently equipped with automated passenger counters. Buses are only equipped with manual counters that must be operated by the bus driver. These counters are used to track the number of persons boarding the bus, by passenger type and fare type.

Unlike vehicle location data, passenger count data collected by individual transit agencies is typically not sent to systems outside the agency such as RIITS.

5.6.3. TRANSIT SIGNAL PRIORITY (TSP) SYSTEMS

In 1998, Metro initiated the Countywide Bus Signal Priority Pilot Project as part of an effort to design, develop, implement, and evaluate a multi-jurisdictional bus priority system for Los Angeles County. This effort brought together multiple jurisdictions and transit operators and led to the development of a wireless signal priority standard for the county. This standard enables buses approaching an intersection to obtain a green extension or early green recall of 8 to 10 seconds, as long as this change does not exceed 10% of the cycle length and no priority has been granted to another bus in the previous cycle. To minimize traffic disruptions, priority requests cannot also be granted to different buses on back-to-back cycles.

Upon the success of the initial pilot, which reduced bus travel times by 4% to 9% and average delays to red signals by 12% to 23%, Metro initiated the Countywide Metro Rapid Signal Priority Expansion Project in 2005. This project first resulted in the implementation of signal priority along four Metro Rapid corridors south of downtown Los Angeles. A second phase, initiated in 2008, added three more corridors by January 2013. One of these corridors, illustrated in red in Figure 5-19 , covers a section of Fair Oaks Avenue in Pasadena served by Metro Rapid Route 762.

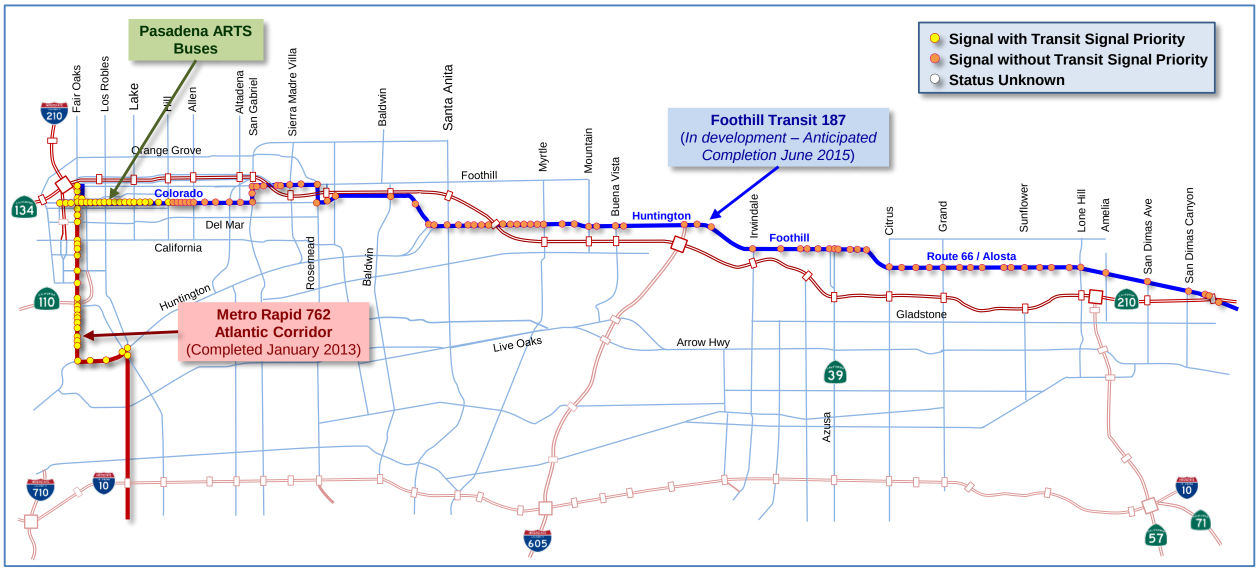


Figure 5-19 – Existing and Projected Transit Signal Priority Corridors

Metro is further collaborating with Foothill Transit to demonstrate signal priority capabilities along the Foothill Transit Route 187 using Metro's Countywide Signal Priority Standard. This route is illustrated in blue in Figure 5-19. As of December 2014, equipment for this corridor has already been procured and installed on buses, and city approval and permits were being sought for the installation of equipment on traffic signals. The anticipated completion data for this project was June 2015.

Other systems outside of the two corridors illustrated in Figure 5-19 may also become operational in the future. While the City of Pasadena has deployed in the past a priority system using the LADOT standards for the city-operated transit buses, this system is believed to be no longer in operation or supported. To replace this system, the deployment of a transit signal priority using Metro's Countywide Signal Priority standard has been actively considered. This new system would include new on-board equipment for the entire fixed-route transit fleet and signal priority equipment for 42 intersections. However, because of a lack of funding, design of this system is not currently scheduled to start before 2018.

5.7. PARKING MANAGEMENT SYSTEMS

This section provides a summary of the parking management systems currently deployed within the I-210 corridor. These systems include:

- Real-time parking occupancy tracking
- Guidance to parking facilities

5.7.1. REAL-TIME PARKING OCCUPANCY TRACKING

Park-and-ride operators within the I-210 corridor do not track the occupancy of the facilities they manage in real time. When required, occupancy data is obtained by sending agency staff to manually survey the number of parking stalls occupied at a given time within a given facility. While some agencies have investigated the potential procurement of systems to track parking occupancy, these efforts have not yet resulted in significant system deployments.

A somewhat different situation exists for general parking facilities operated by cities or private operators. Since most facilities charge a daily use fee, there is a need to assess facility occupancy. Occupancy is commonly determined by using systems counting the number of vehicles entering and exiting the facility. Detectors placed in front of and behind the entry and exit gates to control their operation are used to derive facility occupancy. At facilities without gates where users are required to pay for parking at a kiosk, occupancy can instead be determined by tracking the number of spaces with registered vehicles.

While occupancy may be tracked at some parking facilities for the benefit of the parking operator, the collected occupancy information is not typically made available to information service providers or the traveling public within the I-210 corridor. This may change in the near future if the City of Pasadena completes the planned deployment of a traveler information system to provide motorists with parking availability information within nine of the city-owned parking structures.

5.7.2. ROUTE GUIDANCE TO PARKING FACILITIES

Route guidance to parking facilities within the I-210 corridor primarily consists of static roadside signs installed at key locations to inform motorists which direction to travel to find parking. Aside from the static signs, travelers may also locate parking garages by looking at information on the web or by using specialized parking finder application, such as Park Me. Travelers unfamiliar with the road network may also use mobile navigation applications to obtain directions to a particular parking garage.

No system or application specifically directing travelers to parking facilities with open spaces currently exists within the corridor. Again, this situation will change if the City of Pasadena completes a planned implementation of a dynamic parking guidance system that has been considered for several years for the city's central district. As part of this deployment, informational signs would be installed at the entrance of nine city-owned off-street parking facilities to display the total number of parking stalls available within, and where relevant, on each floor. Additional signs installed at key decisions points throughout the downtown area would further provide occupancy information for several nearby facilities, thus enabling motorists to make an informed decision regarding parking.

5.8. TRAVELER INFORMATION SYSTEMS

Information systems currently in operation along the I-210 corridor include the following:

- Changeable message signs
- Highway advisory radios (HARs)
- NextTrip bus/train tracking information
- 511 traveler information services
- Blue Commute personalized traveler information application
- Offline navigation applications
- Connected mobile navigation applications

5.8.1. CHANGEABLE MESSAGE SIGNS (CMS)

Changeable message signs are used by Caltrans TMC operators to inform motorists about traffic advisories, delays, and emergency conditions. Some CMSs are also used to display estimated travel times to specific locations along the current freeway, as well as comparative travel times to a specific destination along the current freeway and an alternate freeway.

Figure 5-20 maps the location of Caltrans CMSs near the I-210 corridor. Only six signs are located along the study section of I-210. One eastbound sign and one westbound sign are located between the SR-134 and I-605 interchanges. Two westbound and one eastbound signs are located between the I-605 and SR-57 interchange. One westbound sign is located just downstream of the Foothill Boulevard interchange in La Verne. Outside the I-210 corridor, several CMSs can also be used to provide advanced information to motorists traveling towards the I-210 freeway, particularly along the I-605, SR-57, and I-10 freeways.

Figure 5-20 – Caltrans Changeable Message Signs

Within District 7, individual CMSs are controlled through the ATMS application installed at the Los Angeles Regional Traffic Management Center (LARTMC). This application allows the operator to use a map-based display to view which signs have been activated and what messages are currently being displayed. Additionally, automated CMS systems are utilized on various routes in both northern and southern California to provide estimated travel times to commuters. Most of the CMSs used by Caltrans are capable of displaying up to three lines of text, with each containing up to 16 characters. There is a possibility to display messages on alternating screens, this option is not rarely used as it increases the time required to read the displayed messages.

In addition to the Caltrans CMSs, the City of Pasadena has deployed 11 fixed CMSs at key locations within its local street network. Figure 5-21 maps the location of the devices, while Figure 5-22 illustrates a typical installation. As of October 2014, only five of these existing CMSs were operational. The remaining six were legacy devices no longer operational and in need of replacement. Replacement of the non-operational devices was expected to occur in the near future. While the city-operated CMSs are smaller than those Caltrans operates, these devices allow up to three lines of text to be displayed, with up to eight characters per line.

Figure 5-21 – Location of Changeable Message Signs Operated by the City of Pasadena

Figure 5-22 – Example of Changeable Message Signs Operated by the City of Pasadena

5.8.2. HIGHWAY ADVISORY RADIO (HAR)

Figure 5-23 maps the Highway Advisory Radio (HAR) transmitters operated by Caltrans within the Los Angeles County area in June 2013. These are low-powered AM radio stations capable of broadcasting pre-recorded traffic information bulletins in a range of 4 to 6 miles. The map shows 17 fixed-location HAR transmitters, and 2 portable transmitters being used to support construction activities along I-405. A single station is located along I-210, near the I-605 interchange. Other nearby station include two stations along I-10, one near the I-605 interchange and one east of the SR-57 interchange, as well as an additional station near the I-5/SR-2 interchange.

Figure 5-23 – Location and Broadcast Frequency of Highway Advisory Radios in Caltrans District 7

While HAR stations are frequently used in rural areas to inform motorists of traffic-related situations, they are rarely used within the metropolitan Los Angeles area. This is due to the many commercial radio stations within the area broadcasting traffic bulletins every few minutes, particularly during the morning and afternoon peak periods. Since traffic information is already being propagated on mediums accessible by a large proportion of travelers, Caltrans has found little value in using the existing HAR stations to broadcast messages that would not enable travelers to gain more information than what is currently available. In addition, there were some difficulties in determining whether recorded messages were being broadcast as planned, and whether the flashing lights installed on the roadside signs to inform travelers of a message being broadcast were operating correctly. Another detriment to using the HAR stations was the fact that the solar panels used to power the flashing lights were on occasion vandalized or stolen. This occurred for instance for the roadway signals along I-210 and I-605, thus preventing them to be effectively used to inform motorists of a message broadcast.

5.8.3. NEXTTRIP

Real-time vehicle location and projected stop arrival/departure information are available for Metro's buses and trains through an application developed by NextBus, Inc. (now part of Cubic Transportation Systems). Figure 5-24 illustrates the information available for the Metro Gold Line. Similar information is available for all Metro buses. For each transit stop, travelers are provided with the estimated departure times for the next three vehicles along each transit route scheduled to service the stop. In addition to being able to display the information on a map, travelers can also query departure times for a particular bus stop using their cellular phones or SMS (Short Message Service) text messages.

Figure 5-24 – Metro's NextTrip Application

5.8.4. 511 TRAVELER INFORMATION SERVICES

The Southern California Go511 service provides multi-modal traveler information through a 511 interactive voice response (IVR) system and the Go511.com web portal illustrated in Figure 5-25. Go511 is operated by the Los Angeles County Service Authority for Freeway Emergencies (LA SAFE) in partnership with Metro, the Orange County Transportation Authority, the Ventura County Transportation Commission, the CHP, and Caltrans Districts 7, 8 and 12.

Figure 5-25 – Go511 Application

Go511 provides traffic information for the Los Angeles, Orange, Riverside, San Bernardino and Ventura counties. Currently available traveler information services include:

- Real-time traffic speeds along area freeways
- Road construction, lane closures, road closure notices, and incidents
- Access to live video feeds from CCTV cameras operated by Caltrans
- Real time transit departure times
- Bus and train schedules
- Transit trip planner
- Mobile applications for iOS and Android supporting real-time traffic and transit arrival information, transit trip planning, and transit scheduled departures
- General information about toll roads and carpool lanes
- Carpool/vanpool matching application
- Information about regional park-and-ride facilities
- How to obtain roadside assistance

Real-time traffic comes from information collected by traffic detectors embedded into the freeways operated by Caltrans. Planned road and freeway closures for maintenance and construction are also sent by Caltrans. Accidents, incidents and road conditions that affect freeways, such as Sig Alerts, icy roads or flooding, are delivered by the CHP as soon as they are reported. Metro real-time bus arrival information comes from the Nextrip application.

5.8.5. BLUE COMMUTE

Blue Commute is a personalized, $9.99-a-month subscription based travel information application that was developed by Iteris in partnership with LA County Department of Public Works, with additional financial support from Metro, the Federal Highway Administration, the San Bernardino Associated Governments, the Riverside County Transportation Commission, and other agencies. A screenshot of the application's main page is shown in Figure 5-26. It allows travelers to obtain real-time traffic reports via phone and internet on computers, laptops, smartphones, and tablet devices for routes identified by them. Information provided includes:

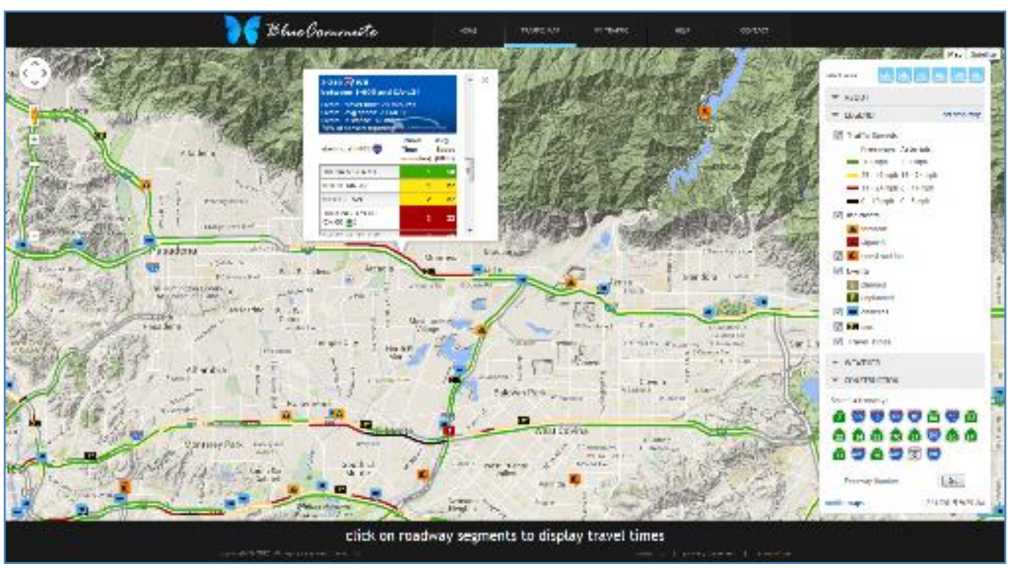


Figure 5-26 – Blue Commute Application

- Congestion information on freeways and arterial roads
- Speeds and travel times on user-selected routes
- Incident notices and construction events along user-selected routes
- Schedule notices pertaining to user-selected routes
- Travel time comparisons for possible routes from point A to point B
- Messages displayed on changeable message signs
- Access to video feeds from CCTV cameras operated by Caltrans
- Call-in service

5.8.6. OFFLINE NAVIGATION APPLICATIONS

Several car manufacturers and GPS equipment manufacturers have been providing GPS-based navigation applications for years. Examples include Garmin and TomTom portable applications and navigation systems installed in vehicles. Most of these applications allow searching possible routes between two locations and provide turn-by-turn directions along the selected routes. Routing is done using a catalogue of maps loaded onto the device containing the applications. If available, travel time estimates are typically based on official speed limits and recommended speeds for various types of roads.

5.8.7. CONNECTED MOBILE NAVIGATION APPLICATIONS

In recent years, several navigation applications for mobile devices have been developed by various manufacturers. The applications all offer similar base functionalities: the ability to search for available routes between two locations according to some criteria, drawing of routes on a map, turn-by-turn navigation instructions along the selected route. Examples of applications currently available include:

- Google Map Navigation
- Apple Navigation
- Waze
- Telenav Scout
- Garmin Viago

All applications use GPS to determine the current location of a vehicle and a set of proprietary or open-sourced maps to determine the best paths to a given location and provide turn-by-turn instructions. Many applications are also providing estimated arrival times. While these estimates were initially based on static data, such as official speed limits or recommended speeds, an increasing number of applications are attempting to provide estimates that would be close to what a traveler might experience. In the most basic systems, travel time estimates are produced by compiling real-time traffic flow data and comparing observed travel times to historical data. The more advanced systems further rely on device tracking and crowd sourcing to collect actual travel times along roadway segments. Lane guidance is another emerging feature that is quickly being adopted. This feature indicates which lane(s) should be used when approaching a junction or intersection.

5.9. INFORMATION EXCHANGE NETWORKS

The following two systems currently enable corridor stakeholders to obtain and/or exchange information about the operations of transportation systems within the I-210 corridor:

- Regional Integration of Intelligent Transportation Systems (RIITS)
- Information Exchange Network (IEN)

5.9.1. REGIONAL INTEGRATION OF INTELLIGENT TRANSPORTATION SYSTEMS (RIITS)

The Regional Integration of Intelligent Transportation Systems (RIITS) network was developed under sponsorship from Metro to provide a platform supporting real-time information exchange among freeway, traffic, transit and emergency service agencies. RIITS' central mission is to support the core business needs of public agencies by creating a one-stop shop for real-time transportation data. It is designed to combine real-time data from various Intelligent Transportation Systems and agencies across Los Angeles County and to provide in return value-added information on the operation of multimodal transportation systems (including freeway, arterial, and transit systems) to partnering agencies, information service providers, and the public. The system is currently the primary provider of Los Angeles County data to the Southern California 511 system.

Figure 5-27 provides an overview of the RIITS architecture. Information provided to the system includes data from the following agencies:

- Los Angeles Metropolitan Transportation Authority (Metro) bus and rail operations
- City of Los Angeles Department of Transportation (LADOT)

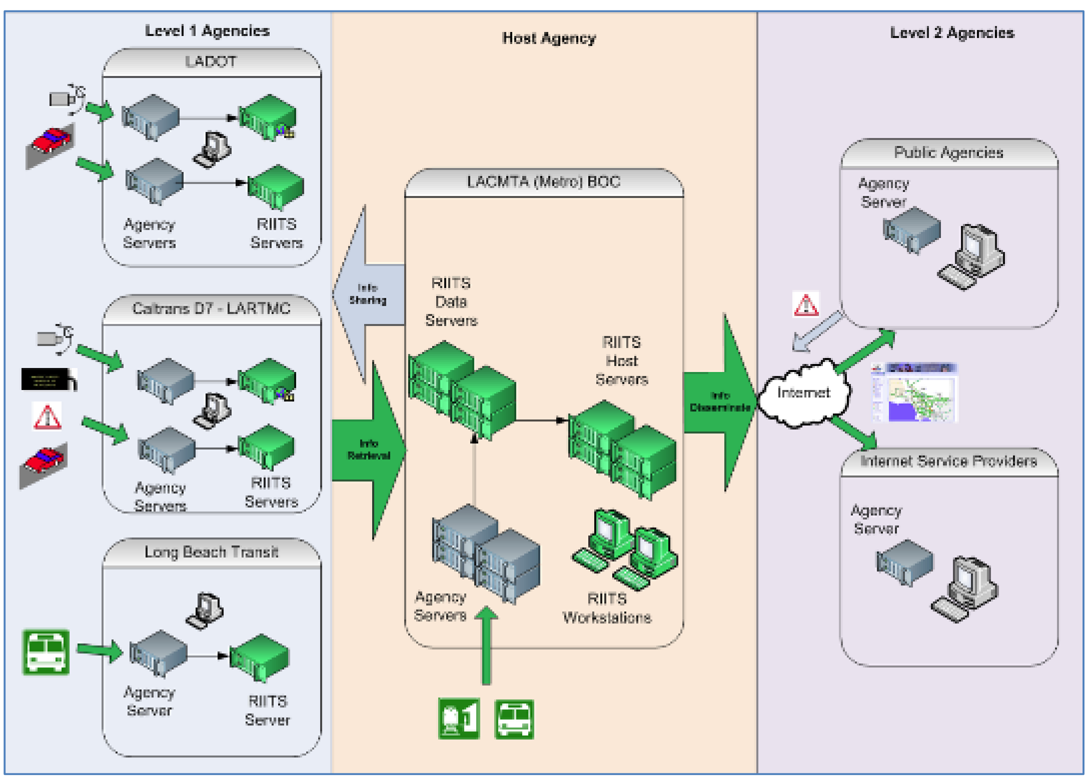


Figure 5-27 – RIITS Architecture

- Caltrans Districts 7, District 8 and District 12
- California Highway Patrol
- Long Beach Transit
- Foothill Transit
- Agencies supplying information to the IEN Network

Within RIITS, partnering agencies have access to the full set of data collected via a secure web-based interface, while information service providers and the public have access to limited data sets through data feeds and a public information website. Partnering agencies have access to freeway and arterial detector data, freeway travel time estimates, changeable message sign data, CCTV data, arterial signal timing data, incident reports from the CHP, events and lane closure data from Caltrans, and transit vehicle location and route data. Data provided to information providers and the public is limited to freeway congestion and travel time data, CCTV video snapshots, and changeable message sign content.

Underlying the interfaces and overall architecture is a communications network linking the various servers. This network includes two fiber optic lines connecting servers at the Los Angeles Regional TMC supporting Caltrans and CHP operations with the LADOT servers, and two lines connecting the LADOT and Metro servers. To enhance communication speed and provide added data exchange capacity, which is currently limited to 2GB per second, plans are being made to place RIITS on Metro's virtual private network (VPN). Data communications are further supported by a series of published standards for data formats and data feeds using the widely adopted XML format and the Traffic Management Data Dictionary (TMDD) V2.1 standard from the Institute of Transportation Engineers (ITE).

While RIITS has been successful in providing baseline transit, traffic, and incident data to its users, the following issues were identified in RIITS' 2010 ten-year strategic development plan:

- The absence of data archival prevents historical data analyses
- Current network speed/capacity is not enough to handle additional enhanced functionality such as filtered data feeds and database queries
- Since the system does not currently store any data, it does not facilitate the review of transportation conditions over time
- While sufficient for current needs, network security needs to be upgraded in order to ensure the privacy of future data contributors

Table 5-3 identifies the data feeds available through RIITS. The table distinguishes two types of data feeds: a data feed that can only be accessed by transportation agencies connected to the system, and a feed providing limited data to information service providers. If should also be noted that the listed data types may not be available from all devices or systems operated by an agency. Data availability depends on whether data-supplying devices are connected to RIITS and have been configured within the system.

Data latency between when a piece of information is collected from a source agency to the time it is available on the RIITS system outputs generally varies from roughly 1 to 2 minutes. RIITS is further dependent on source systems for information and is subject to the limitations of those source systems in terms of accuracy and timeliness of data.

Table 5-3 – RIITS Data

Data Source	Data	Update Rate	Availability		
			Agency Feed	Map	ISP Feed
Caltrans District 7	Freeway detector inventory data	Daily (midnight)	●		
	Arterial detector inventory data	Quarterly	●		
	Freeway traffic detector data	1 minute	●	●	●
	Arterial traffic detector data	1 minute	●	●	
	CMS inventory data	Daily (midnight)	●		
	CMS messages	1 minute	●	●	
	CCTV inventory data	Quarterly	●		
	CCTV snapshots	1 minute	●	●	●
	Freeway closure data (next 24 hours)	1 minute	●		
Los Angeles Dept. of Transportation (LADOT)	Arterial detector inventory	Daily (midnight)	●		
	Arterial traffic detector data	1 minute	●	●	
CHP - Los Angeles	Incident reports	1 minute	●	●	
Metro Bus Operations	Route data	Quarterly	●	●	
	Vehicle location data	2 minutes	●	●	
Metro Rail Operations	Route data	Quarterly	●	●	
	Vehicle location data	1 minute	●	●	
Long Beach Transit	Route data	*Unknown*	●	●	
	Vehicle location data	1 minute	●	●	
Foothill Transit	Route data	*Unknown*	●	●	
	Vehicle location data	1 minute	●	●	

5.9.2. INFORMATION EXCHANGE NETWORK (IEN)

The Information Exchange Network (IEN) is an information-sharing network that was developed by TransCore for the Los Angeles County Department of Public Works in the early 2000s. It was established to enable the sharing of traffic signal control information, and eventually traffic signal control itself, across the various systems used within the county. Unlike many other information-sharing systems, its primary focus is on traffic signal control rather than freeway management. Key features of the IEN include:

- Use of a common system interface definition language (IDL) to enable heterogeneous traffic control systems to be connected onto the IEN backbone
- Ability to process second-by-second intersection data to support real-time intersection displays, section displays, and arterial coordination
- Ability for agency operators to change the plan/mode of signalized intersections through pop-up control windows
- Ability for smaller agencies to relinquish control and monitoring of devices to another agency for off-hours support and maintenance
- Ability to collect data from PeMS and RIITS, thus enabling the system to report freeway congestion status, incidents, and lane closures
- Ability for participating agencies to share incident, planned event and construction activities information through an incident and planned events tracking system
- Ability to establish multi-agency incident response with a scenario manager

Figure 5-28 illustrates the basic system architecture. As illustrated, the IEN is a multi-tiered, hierarchical system with site, regional, and external interface components. Site components installed at participating agencies typically include:

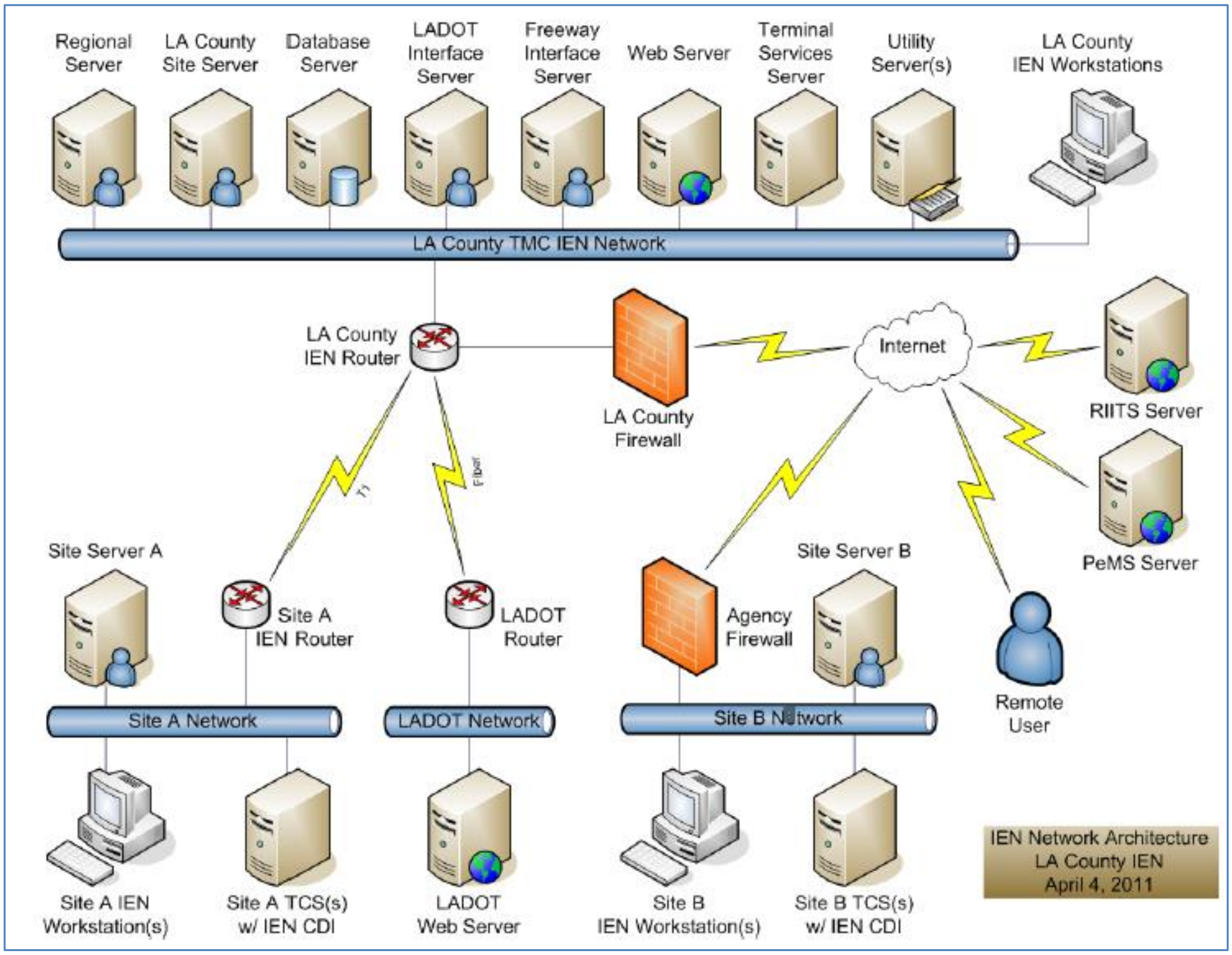


Figure 5-28 – IEN System Architecture

- A site server to manage the distribution of data between local workstations, local traffic control systems, and the regional server
- One or more workstations to run the IEN user interfaces
- Command/data interface software connecting the IEN site server to a traffic control system
- A network firewall to enforce secure connections between the IEN and agency networks

Regional IEN components are located at the Los Angeles County Department of Public Works and provide the central servers for the IEN System. These components include:

- One or more regional servers to manage the distribution of data between sites
- A database server to maintain system configuration information and historical status, event management, and alarm data
- Utility servers providing supporting services, such as active directory, domain name system, and time synchronization
- Terminal services servers to provide access to the IEN Workstation software for remote users that connect to LA County's Virtual Private Network (VPN)

As of December 2014, agencies within the I-210 corridor connected to the IEN network include:

- Los Angeles County Department of Public Works

- City of Pasadena
- City of Arcadia
- City of Alhambra
- City of West Covina
- Caltrans (via RIITS)

In addition to the above connections, the LA County Department of Public Works is currently developing an interface that will allow any jurisdiction using the KITS signal control system to communicate with the IEN. For the I-210 corridor, this will enable to communicate data from signals operated by the cities of Duarte and Monrovia in addition to data from County-operated intersections.

The IEN is designed to collect continuously intersection controller and arterial system detector data from the various traffic control systems connected to it. The IEN polls each device once every minute for a full set of summary status data and simply for status updates during the remaining 59 seconds. To avoid overwhelming traffic control systems with data requests, full data are only polled from 1/60 of all devices are polled each second, thus enabling all devices to be polled in one minute.

Table 5-4 – IEN Data

Data	McCain QuicNet	TransCore Series 2000	Siemens i2tms	TransCore TransSuite
Traffic Control System Data				
Description	●	●	●	●
Signal type	●	●	●	●
Latitude/Longitude	●	●	●	●
Main street			●	
Cross street			●	
Communication state	●	●	●	●
Timing plan	●	●	●	●
Desired cycle length	●	●	●	●
Desired offset	●	●	●	●
Actual offset	●	●	●	●
Signal control mode	●	●	●	●
Signal state	●	●	●	●
Last cycle length	●	●	●	●
Last cycle phase green times	●	●	●	●
Planned phase maximum green times	●	●	●	●
Traffic Detector Data				
Associated intersection number	○	○	○	○
Averaging period	●	●	●	●
Road name				●
Cross street name	○	○	○	○
Travel direction	●		●	●
Description text	○	○	○	○
Detector state	●	●	●	●
Traffic volume	●	●	●	●
Detector occupancy	●	●	●	●
Traffic speed		●	●	●
Average traffic volume	●	●	●	●
Average detector occupancy	●	●	●	●
Average traffic speed	●	●	●	●

● Currently available ○ Planned to be added at RIITS's request

Table 5-4 lists the data collected by the IEN system. It is important to note that while a traffic control system may be capable of supporting a particular type of data, data may not be available for a given device because it has not been configured within the traffic control system. For example, detector direction and road name are usually optional fields within traffic control systems that many agencies have not entered and therefore are not available to the IEN. The availability of data depends on the combined status and capabilities of the device, traffic control system, field-to-central communications, and command/data interface. As an example, devices connected to McCain's QuicNet systems only report actual offset and planned phase max green times for controllers running McCain's 233RV2 firmware, in addition to communicating at a minimum baud rate of 9600.

The IEN, the participating traffic control systems, and the Internet are interconnected distributed systems with inherent and variable data transfer latencies. The data that the IEN receives from traffic control systems can therefore be several seconds old. Data will age further by the time it reaches an external system through the IEN Web Server

6. CURRENT OPERATIONAL STATUS

This section provides an assessment of the current operational situation along the corridor. The objective of this assessment is to identify operational gaps, constraints and problems affecting systems operations. Operational elements of the I-210 corridor reviewed herein include:

- Travel demand
- Freeway operations
- Arterial operations
- Transit operations
- Parking management

6.1. TRAVEL DEMAND

This section characterizes the traffic demand for the I-210 freeway and surrounding arterials. Elements covered in this section include:

- Profile of trips originating, destined, or passing through the I-210 corridor
- Demand for travel along the I-210 freeway
- Demand for travel along key corridor arterials

6.1.1. CORRIDOR TRIP PROFILE

Information about trip patterns along the I-210 corridor presented in this section is extracted from the facility's Corridor System Management Plan (CSMP) that was released in September 2010. This characterization, which was completed in 2008, was developed using Caltrans' version of the Southern California Association of Governments (SCAG) Regional Travel Demand Model for the year 2000. This was the latest model available at the time of the evaluation (the 2003 model was released in January 2008, and the 2008 model subsequently released in January 2012). The CSMP analysis identified the origin and destination of trips made along the I-210 corridor using the aggregate zonal system shown in Figure 6-1.

Figure 6-1 – 2010 CSMP Travel Demand Analysis Zones

Reflective of the CSMP objectives, the I-210 corridor defined in this analysis extends from the I-5 interchange in San Fernando to the Los Angeles County / San Bernardino County boundary, approximately 7 miles east of the SR-57 interchange in San Dimas. While this is longer than the corridor under consideration, it includes in its entirety the section of I-210 being evaluated.

Table 6-1 – AM Peak Travel Patterns

	I-210	Southern LA	Northern LA	Orange County	Riverside	San Bernardino	Ventura	Outside Zone	Total Origin
I-210	83,477	49,842	3,872	3,230	622	3,431	2,886	483	**147,843**
Southern LA	37,275	2,703	504	31	129	518	154	225	**4,301**
Northern LA	7,780	1,766	76	61	29	95	76	14	**9,897**
Orange County	2,852	45	12	0	0	0	13	74	**2,996**
Riverside	1,678	286	9	0	0	0	23	113	**2,109**
San Bernardino	7,932	1,652	71	3	0	0	105	99	**9.862**
Ventura	2,006	103	50	10	45	109	0	33	**2,356**
Outside Zones	280	180	9	21	85	90	10	336	**1,011**
Total Dest.	**106,042**	**56,577**	**4.603**	**3,356**	**910**	**4,243**	**3,267**	**1,377**	**180,375**

Table 6-2 – PM Peak Travel Patterns

	I-210	Southern LA	Northern LA	Orange County	Riverside	San Bernardino	Ventura	Outside Zone	Total Origin
I-210	122,552	58,306	10,380	4,747	2,271	11,035	2,886	597	**212,774**
Southern LA	74,797	2,809	1,617	122	409	2,048	154	363	**82.319**
Northern LA	7,297	1,092	133	53	43	155	76	16	**8,865**
Orange County	5,735	55	96	0	0	1	13	111	**6.011**
Riverside	1,306	248	27	0	0	0	23	135	**1,739**
San Bernardino	7,103	1,275	167	3	0	0	105	125	**8.778**
Ventura	2,056	103	55	14	46	134	0	46	**2,454**
Outside Zones	1,062	546	23	284	341	278	15	1,164	**3,713**
Total Dest.	**221,908**	**64,434**	**12,498**	**5,223**	**3,110**	**13,651**	**3,272**	**2,557**	**326,653**

Table 6-1 and Table 6-2 show the result of the trip pattern analysis for the AM and PM periods respectively. For the AM peak, Table 6-1 shows that 87% of trips made along the I-210 corridor are entirely contained within Los Angeles County, i.e., have both an origin and destination within the county. The data notably suggests that a large percentage of AM peak traffic uses the I-210 freeway to connect to other freeways heading south to southern Los Angeles County. A more detailed analysis further reveals that:

- 39% of trips made along the corridor have both an origin and destination within the corridor
- 41% of trips are originating from or destined to southern Los Angeles County, which includes downtown Los Angeles and the urban core of the region
- 7% of trips represent travel to other sections of Los Angeles County
- 8% originate outside Los Angeles County and terminate within the county
- 5% of trips originate from Los Angeles County and terminate in other counties
- 1% of trips start and terminate outside Los Angeles County

For the PM peak period, the data of Table 6-2 indicates a much higher travel demand. For this period, the analysis indicates a 52% higher travel demand than from the AM peak period. The analysis also indicated that the traffic patterns observed during the morning repeat in the afternoon, with 85% of trips entirely contained within Los Angeles County. More specifically, the analyses suggest that:

- 38% of trips made along the corridor have both an origin and destination within the corridor
- 41% of trips are originating from or destined to southern Los Angeles County, which include downtown Los Angeles and the urban core of the region

- 6% of trips represent travel to other sections of Los Angeles County
- 8% originate outside Los Angeles County and terminate within the county
- 6% of trips originate from Los Angeles County and terminate in other counties
- 1% of trips start and terminate outside Los Angeles County

6.1.2. I-210 TRAVEL DEMAND

This section characterizes the demand for travel along the I-210 freeway. This characterization is performed through the following analyses:

- Average daily traffic (ADT) volumes along various sections of I-210
- Average daily vehicle-miles traveled (VMT) along the portion of I-210 extending from the SR-134 interchange through the SR-57 interchange
- Truck movements within the I-210 corridor
- Weekday variability of vehicle-miles traveled along the freeway

Figure 2 presents the average number of vehicles that have been observed to travel daily along various sections of the freeway between May 2013 and April 2014 for each travel direction. These statistics

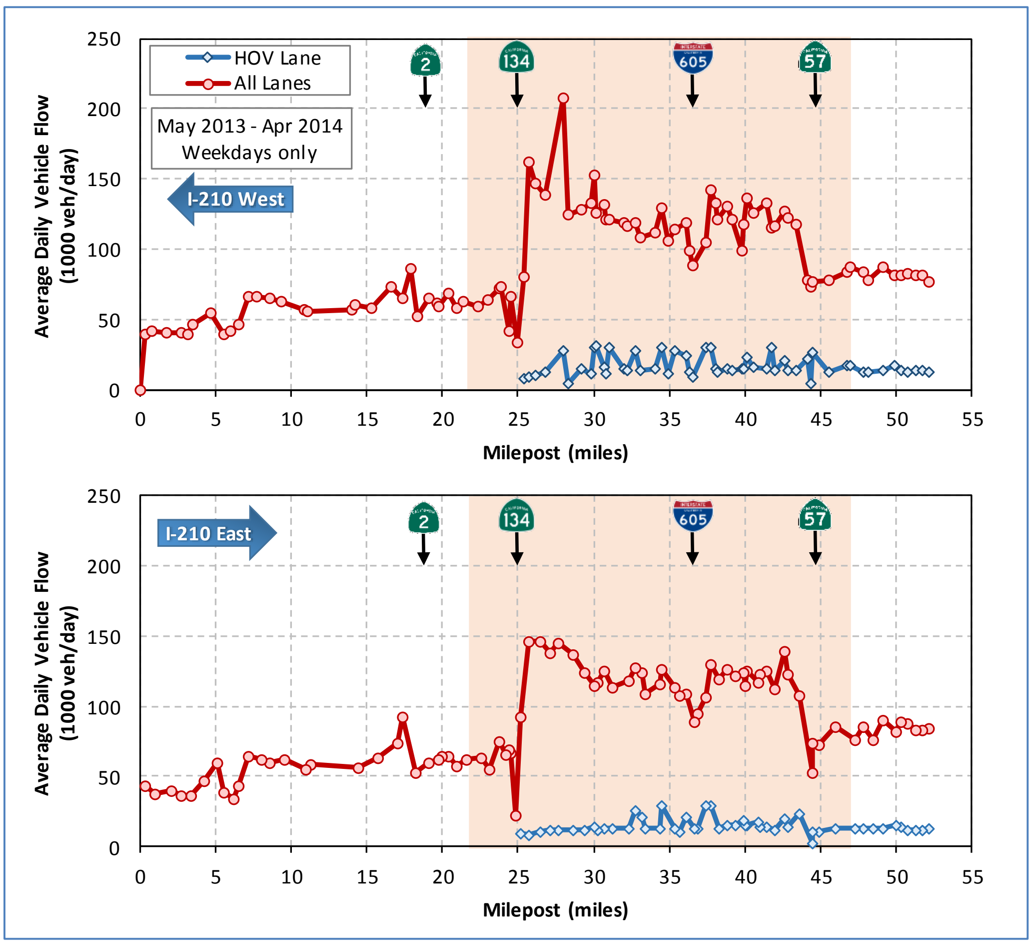


Figure 2 – Average Daily Weekday Traffic Flow at Various Locations along I-210

were retrieved from PeMS in May 2014 and are derived from vehicle count data generated by traffic detectors operated by Caltrans along the freeway mainline. Each graph shows the total average daily traffic over all traffic lanes and the portion of the total traffic that traveled on the facility's HOV lane east of the SR-134 interchange. The shaded area in the middle of the graphs further represents the section of I-210 that is of primary interest for the development of the pilot ICM system. As can be expected, traffic along I-210 is heaviest between the SR-134 and SR-57 interchanges, with the peak traffic just east of the SR-134 interchange near downtown Pasadena. Within this segment, between 100,000 and 150,000 vehicles are observed to travel daily along I-210 in both the eastbound and westbound directions, with slightly higher traffic volumes observed in the westbound direction. In both directions, the HOV lane is observed to carry between 10,000 and 30,000 vehicles per day depending on the section considered, with the highest volumes again observed in the westbound direction.

At the SR-134 interchange, the significant change in observed traffic volume is associated with the geometry of the interchange. As shown in Figure 3, the main freeway lanes along I-210 east of the interchange directly connect with the SR-134 freeway Traffic destined to or coming from the I-210 freeway north of Pasadena has to take a two-lane connector to transfer between the two sections of the I-210 freeway. The flow drop observed in the graphs of Figure 2 reflect both the constrained capacity of the connector and the fact that a significant portion of the I-210 traffic east of the interchange either comes from SR-134 or is destined to this freeway.

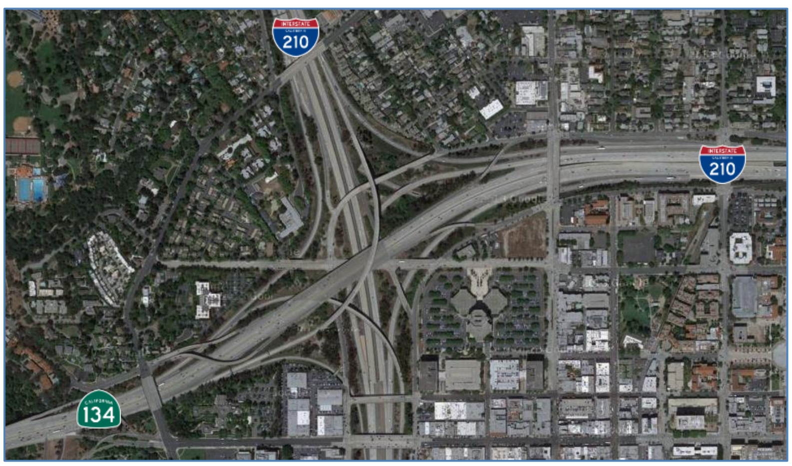


Figure 3 – I-210/SR-134 Interchange

The flow drops observed at the I-605 and SR-57 interchanges are similarly reflective of a large proportion of vehicles entering or exiting the I-210 freeway at these locations. At each interchange, the data point with the smaller volume corresponds to a detection station located between the ramp carrying the traffic exiting the I-210 freeway and the ramp bringing traffic onto I-210 from the intersecting freeway. These data points thus represent the proportion of traffic along I-210 that does not enter or leave the freeway at these locations.

6.1.2.1. Average Vehicle Miles Traveled (VMT)

Figure 4 presents another measure of travel demand. The graphs shown in the figure track the total vehicle-miles traveled for each travel direction along I-210 between the SR-134 interchange in Pasadena and the Foothill Boulevard interchange in La Verne during non-holiday weekdays between January 2008 and April 2014. In each graph, the vertical bars illustrate the average daily VMT for each month that was

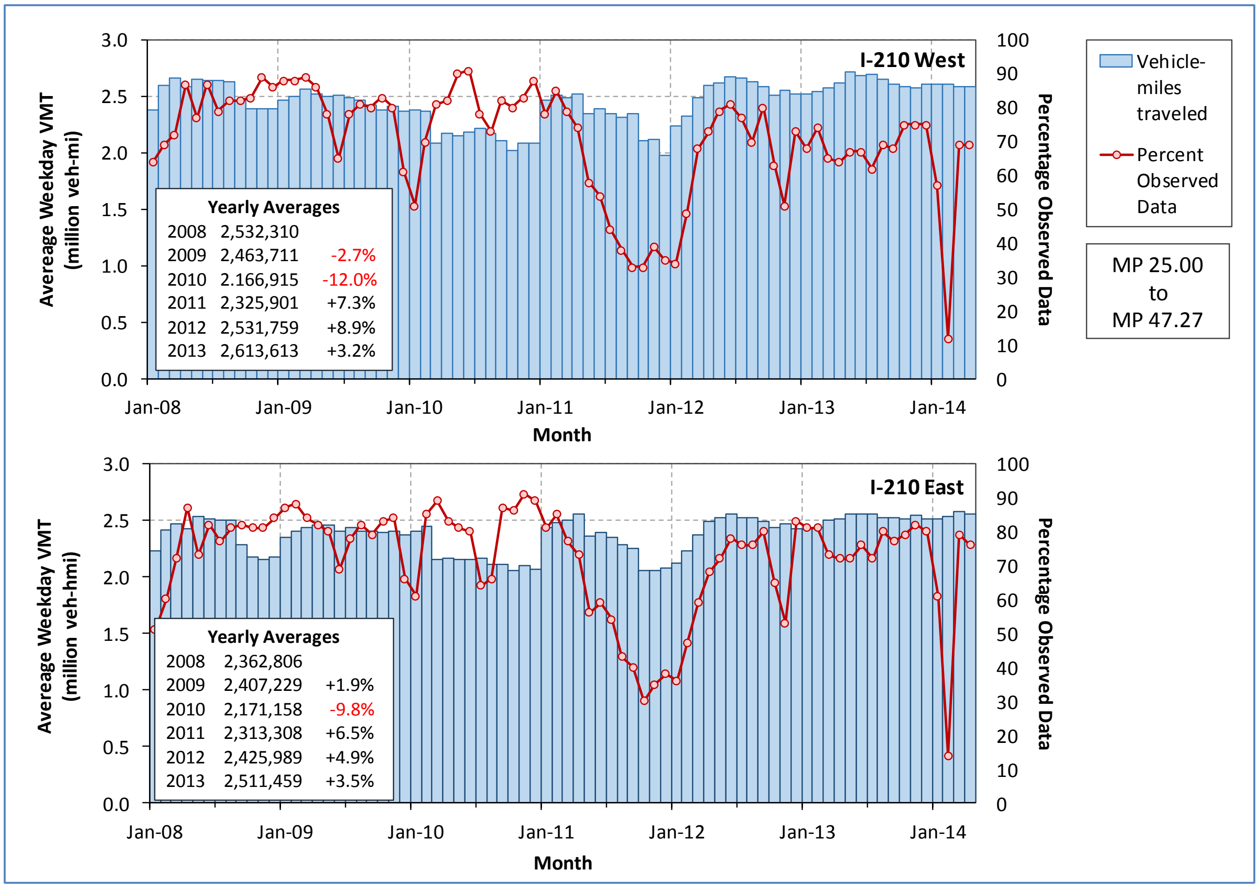


Figure 4 – Average Daily VMT between Mileposts 25.00 and 47.27, by Month

estimated by PeMS from traffic counts along the freeway mainline, while the table on the lower left corner shows the average daily VMT for each full year covered within the analysis period. To help assess data quality, the red line further presents the percentage of the vehicle counts at the base of the VMT estimates that were obtained from direct sensor measurements, i.e., that have not been subject to imputation by PeMS using data from nearby detectors or other sources.

The graphs of Figure 4 first indicate that approximately 2.5 million vehicle-miles are traveled each month in each direction of I-210, with a slightly higher number of traveled miles in the westbound direction. The graphs also indicate that following reductions in 2009 and 2010, vehicle miles traveled along the I-210 are 3 to 6 percent higher than in 2008, the year that was used as a reference to develop the 2010 Corridor System Management Plan (CSMP) for the I-210. As can be observed, this growth was preceded by a period of significant fluctuations in VMT. Various factors can explain these fluctuations. The drop observed at the end of 2008 can first be attributed to the financial crisis that hit in the fall of 2008. The second significant drop observed to occur in March 2010 and to last until December 2010 is in turn likely the result of shifted travel patterns due to road construction that occurred along the freeway at that time. Finally, the concordance between the drop in VMT and drop in the percentage of observed data between January 2011 and June 2012 suggests that the likely cause of the observed drop in VMT during this period can be attributed to sensor problems.

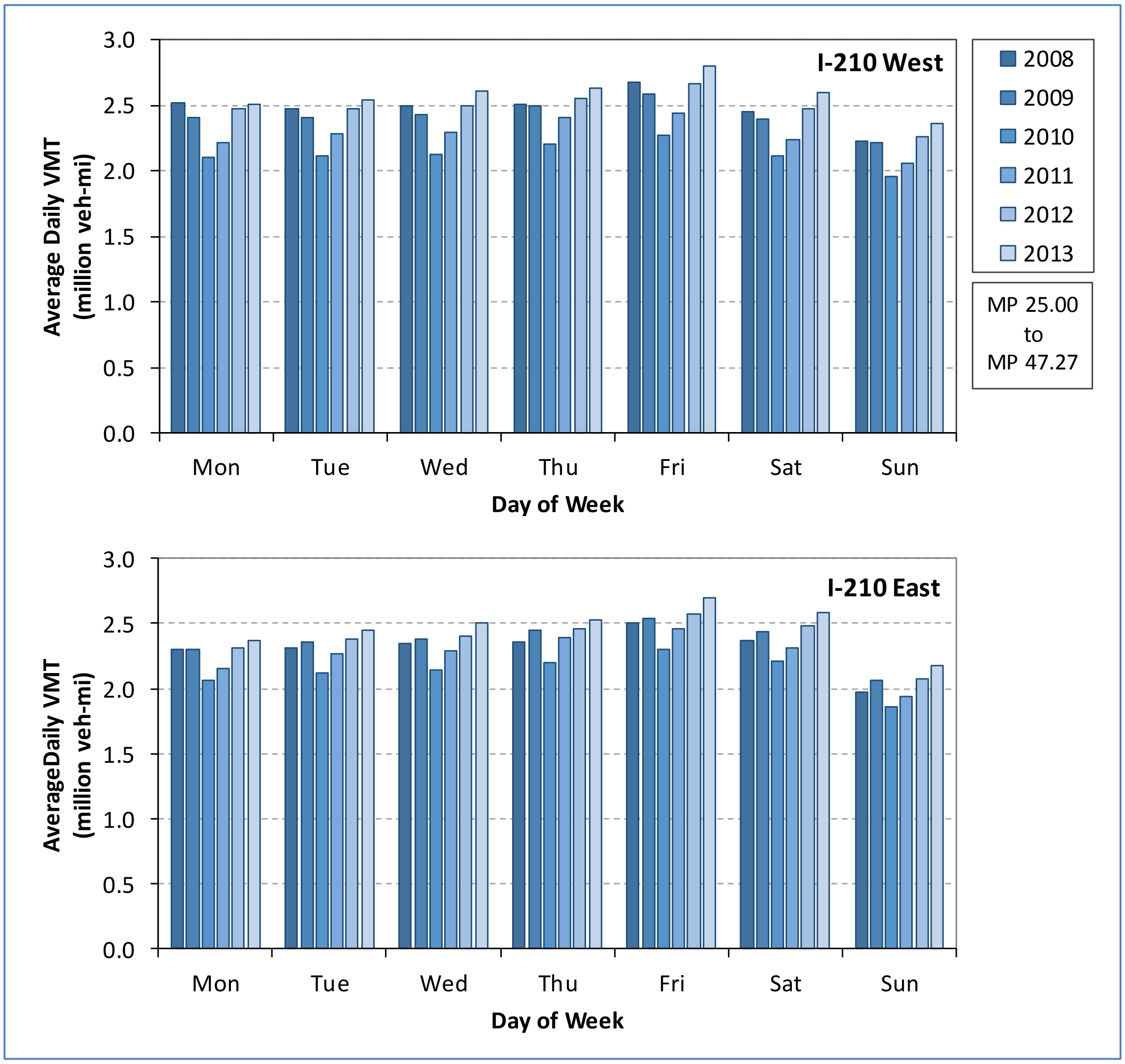


Figure 5 – Average Daily VMT between Mileposts 25.00 and 47.27, by Day of Week

Figure 5 further compares the average daily VMT in each travel direction for each day of the week. For both directions, traffic demand is found to be lowest on Monday and to increase gradually as the week progresses, reaching a peak on Friday. In the westbound direction, the data indicates an average increase of 8% from Monday to Friday. In the eastbound direction, the average increase is 11%. These trends are relatively consistent across the years. A relatively high traffic demand is also commonly observed on Saturday, with VMT values similar or exceeding those associated with some of the early weekdays. Finally, as expected, the lowest traffic demand typically occurs on Sunday.

6.1.2.2. Truck Operations

This section provides an assessment of current truck operations along the I-210 corridor. This assessment is based on a truck origin-destination survey that was commissioned from Minagar & Associates by Metro in March 2011 and released in January 2012 and which specifically covered the 20-mile section of I-210 extending from the SR-134 to the SR-57 interchanges. This study assessed truck movements based on vehicle classification, origin-destination, vehicle commodity type, route selection, and turning counts; video data collected near the I-605 and I-210 freeways; and a survey of truck drivers.

The following is a summary of the key findings of the study regarding trucking activities on I-210:

- 55% of trucks traveling on I-210 are large, heavy-duty trucks with 3 or more axles and having a minimum weight of 13 tons (26,000 lbs). The remaining 45% are commercial vehicles having a lighter weight or fewer axle-tire combinations, such as two-axle service/delivery trucks and recreational vehicles
- As shown in Table 6-3, trucks accounted for 6.2% of the total I-210 traffic in 2011, with heavy-duty trucks accounting for 4.4% of the total traffic

Table 6-3 – Proportion of Trucks on I-210 and Surrounding Freeways (2011 Data)

Freeway	Section	Heavy Duty Trucks	Light-Duty Trucks	All Truck Types
I-210	SR-134 to SR-57	4.4%	1.8%	6.2%
SR-134	West of I-210	1.3%	1.2%	2.5%
I-605	SR-60 to I-210	5.1%	3.5%	8.6%
SR-57	SR-60 to I-210	5.1%	2.6%	7.7%

- On a section-by-section basis, trucks accounted between 3.4 and 7.8% of the I-210 mainline traffic in 2011, with the highest proportions of trucks occurring just west of the I-605 interchange. When considering only heavy-duty trucks, the proportion of trucks varied between 2.3% and 5.2% (see Figure 6-6)
- On most on-ramps and off-ramps, heavy-duty trucks typically account for less than 1% of the total ramp traffic. A significant exception is for the Irwindale interchange, where heavy-duty trucks represent 9% of the AM peak and 13% of the midday traffic in 2010, with proportions on specific ramps reaching up to 19%

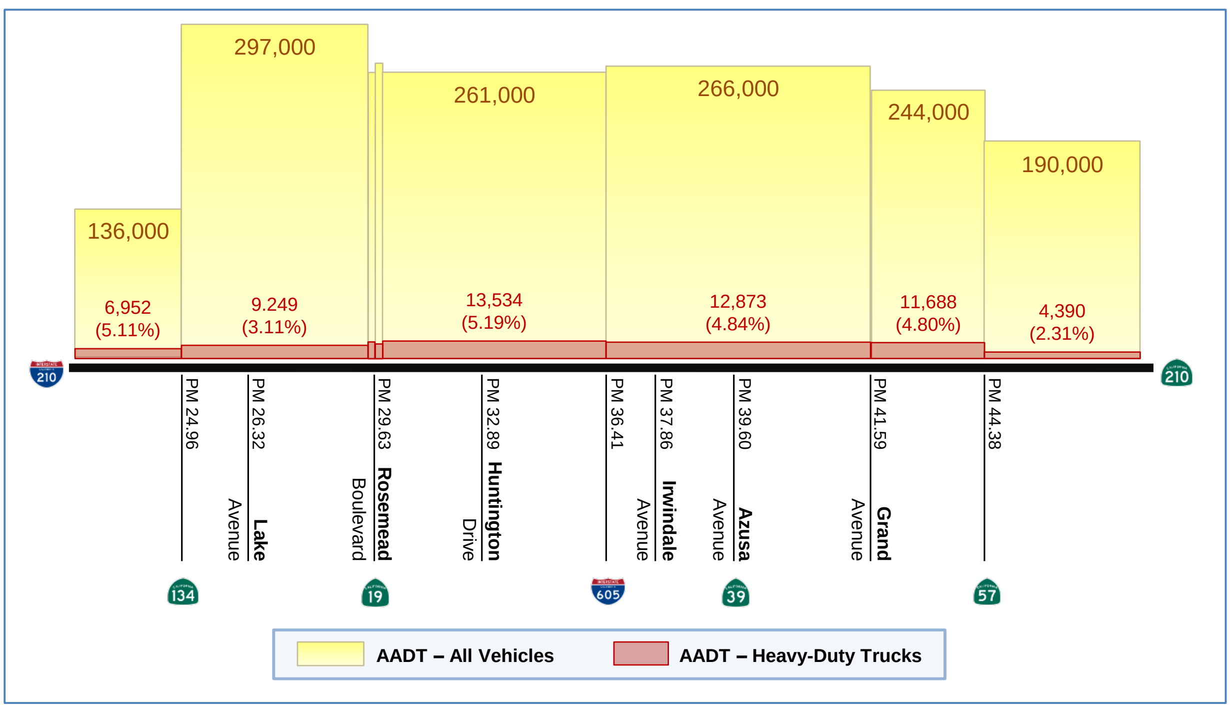


Figure 6-6 – Proportion of Trucks along I-210 Sections (2011 Data)

Key findings regarding the demand profile for truck traffic along the I-210 corridor are as follows:

- The peak period for heavy-duty truck traffic is between 9:00 AM and 1:00 PM
- Eastbound heavy-duty truck volumes are typically 28% higher than westbound volumes
- Contrary to a commonly held view, heavy-duty truck traffic on arterials is highest on Fridays, not on Mondays or Tuesdays
- Approximately 20% of local freight operators experience seasonal activity peaks. Depending on the operator, this peak occurs either during the summer months or during the winter months

Finally, key findings regarding the origins and destinations of truck traffic along the corridor are as follows:

- Throughout the day, the section of I-210 west (north) of the SR-134 interchange and the SR-57 freeway at the east end are the two main heavy-duty truck entry and exit points. Significant proportions of trucks enter and exit using the I-605 freeway and I-210 freeway at the east end of the corridor. Relatively few trucks use the SR-134 freeway, except during the PM peak period when a large proportion of trucks is often observed exiting the corridor towards Burbank and Los Angeles via SR-134 (see Figure 6-7)
- According to the survey of truck drivers conducted by Minagar & Associates, many truck drivers choose to travel along I-210 as an alternate route to other congested freeways
- As illustrated in Figure 6-8, 45.5% of truck traffic on I-210 originates from locations within the San Gabriel Valley. An additional 36.5% of trips originate from other areas of Los Angeles County
- As illustrated in Figure 6-9, 48.9% of trips made by heavy-duty trucks along I-210 are destined to a location within the San Gabriel Valley. An additional 32% of trips are destined to locations elsewhere in Los Angeles County

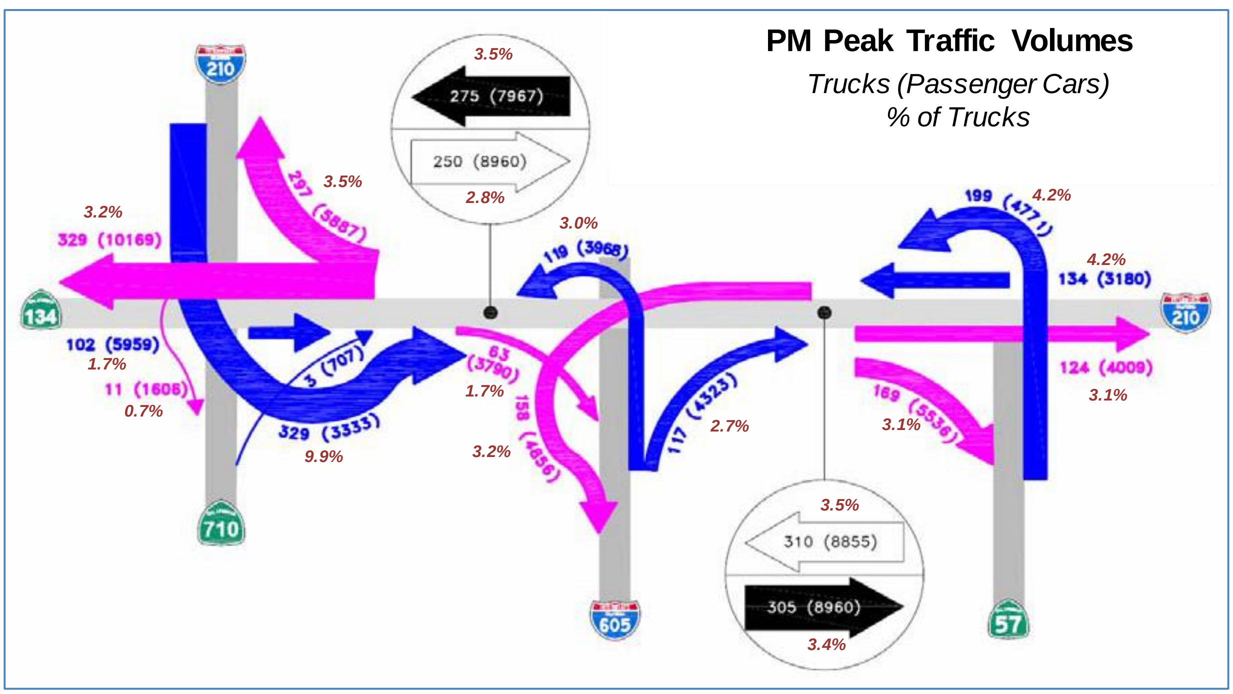


Figure 6-7 – PM Peak Main Truck Entry and Exit Points along I-210 (2010 Data)

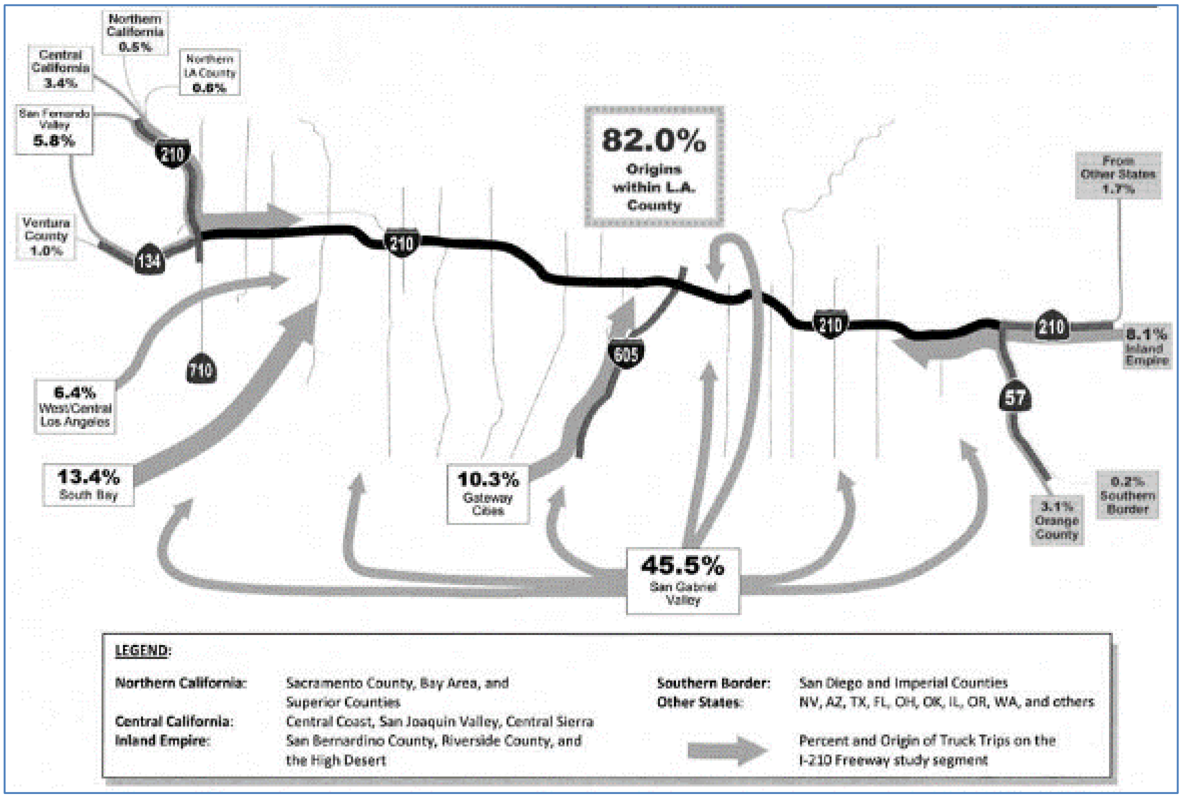


Figure 6-8 – I-210 Truck Traffic Origins

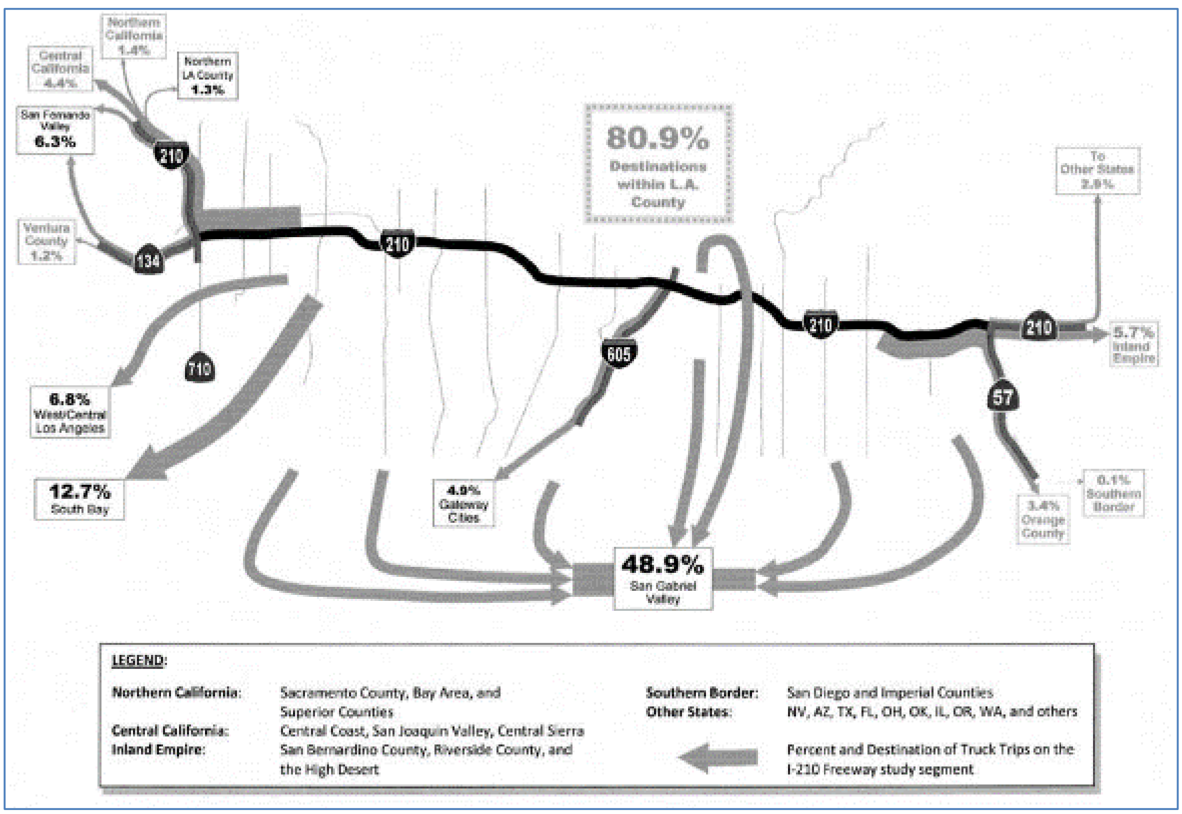


Figure 6-9 – I-210 Truck Traffic Destinations

6.1.2.3. Travel Demand Variability

Figure 6-10 characterizes the variability of traffic demand along the I-210 freeway by illustrating the variability of vehicle-miles traveled (VMT) along the freeway on a specific weekday and hour of the day. For each travel direction and weekday, the figure illustrates the average VMT, as well as values corresponding to the average plus or minus one standard deviation and values corresponding to the 5th and 95th percentile of observations based on vehicle count data collected by freeway mainline traffic detectors. The data sample used in this analysis include data from all I-210 mainline traffic sensors from the Arroyo Boulevard interchange in Pasadena (Exit 22B) to the Foothill Boulevard interchange in La Verne (Exit 47) that were collected by PeMS between September 4 and November 16, 2013. In the westbound direction, this data set include on average 77% of direct observations and 23% of imputed data from historical data or data from nearby detectors. In the eastbound direction, it includes 73% of observed data and 27% of imputed data. The interval bounded by one standard deviation illustrates the range of hourly VMT estimates that includes 68% of observed values if it is assumed that VMT follows a normal statistical distribution. The 5th and 95th percentiles represent extreme demand values that may on occasion be observed. While VMT values can exceed the 5th and 95th percentile boundaries on occasion, such values can be assumed to represent highly unusual traffic conditions and cannot reasonably be expected to be observed during typical day-to-day operations.

Analysis of the data of Figure 6-10 leads to the following general observations:

- As expected, traffic demand fluctuates quite significantly within each weekday.
- In each direction, traffic patterns on Monday, Tuesday, Wednesday and Friday are relatively similar. Each day feature a morning and an afternoon peak period, with the two periods bridged by a period of relatively high demand.
- Traffic patterns on Saturday and Sunday are relatively similar and significantly different from other weekdays. On both days, traffic tend to increase until mid-afternoon, at which point it gradually starts to decrease before reaching a minimum early in the night.
- For each weekday, there is a relatively small variability in traffic demand from one week to the next when, particularly when compared to the variability across the hours of a day.
- Between 6:00 AM and 8:00 PM on weekdays, the VMT typically vary by less than 5% around the estimated average from one week to the next over the observation period, with the largest fluctuations reaching approximately 10%.
- While a significant portion of the observed variability can be attributed to normal fluctuations in travel demand, such as motorists deciding to start a trip earlier or later, some of the larger fluctuations may be attributed shifts in traffic patterns due to events and incidents. Such events may either entice motorists to take an alternate route away from I-210, or push traffic from other freeways or arterials onto the I-210.

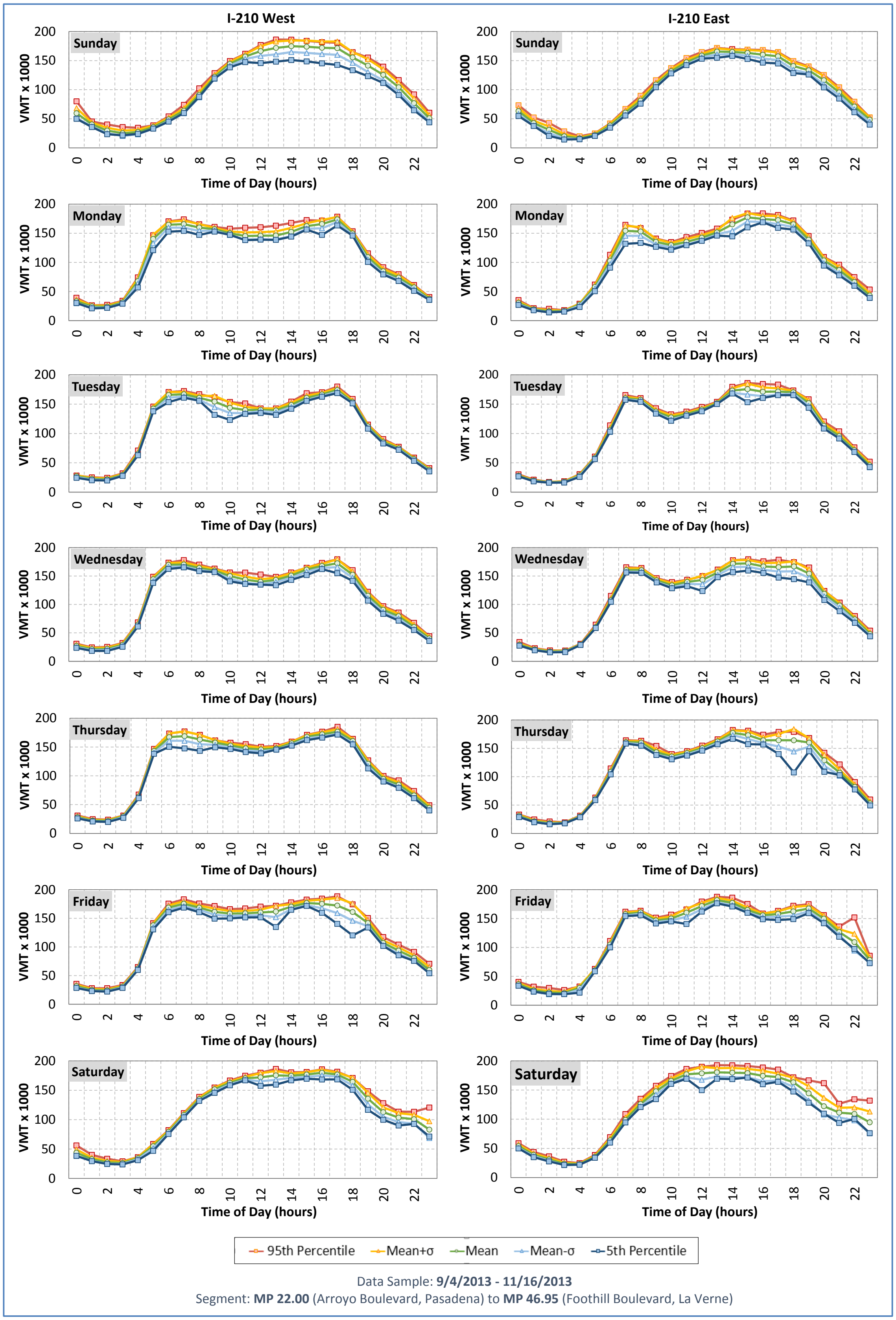


Figure 6-10 – I-210 Mainline VMT Variability between Arroyo Boulevard and Foothill Boulevard

6.1.3. ARTERIAL TRAVEL DEMAND

This section characterizes the current demand for travel on the corridor arterials. This characterization is primarily achieved through a compilation of mid-block traffic counts that have been executed over the past several years by the various jurisdictions in the corridor for transportation planning purposes or in support of traffic impact studies associated with specific development projects. While relatively limited, a summary of available information about truck movements on corridor arterials is also provided.

6.1.3.1. Arterial Traffic Volumes

Figure 6-11, Figure 6-12, and Figure 6-13 present the average daily traffic volumes that have been derived from traffic counts for various arterial roadway links across the I-210 corridor by various local jurisdictions. Each graph presents the total number of vehicles that have been counted on the given roadway links, in both travel directions, over a 24-hour period on a normal weekday. The following are key observations that can be derived from the statistics:

- **Pasadena (**Figure 6-11**)** – Within Pasadena, the highest traffic volumes are typically observed on Lake Avenue between Colorado Boulevard and Washington Boulevard, as well as on sections of Fair Oaks Avenue and Arroyo Parkway south of California Boulevard. On a normal weekday, these arterial segments carry between 30,000 and 40,000 vehicles. 24-hour volumes exceeding 20,000 vehicles are also observed on sections of Colorado Boulevard, Del Mar Boulevard, California Boulevard, Orange Grove Boulevard, Allen Avenue, Altadena Drive, San Gabriel Boulevard, Sierra Madre Boulevard, and Foothill Boulevard.
- **Arcadia (**Figure 6-12**)** – Within Arcadia, the busiest arterials are Huntington Drive, Foothill Boulevard, Baldwin Avenue, Santa Anita Avenue, and Live Oak Avenue. These facilities all feature segments carrying over 25,000 vehicles per day. Within the group, the busiest section is Huntington Drive west of Holly Avenue, with a 24-hour traffic volume oscillating between 31,000 and 35,000 vehicles. Daily traffic volumes exceeding 20,000 vehicles are also observed on sections of Duarte Road, Sunset Boulevard, and Las Tunas Drive.
- **Monrovia** – No count data were found for the City of Monrovia. Since both Huntington Drive and the section of Myrtle Avenue south of Huntington Drive are designed as primary arterials, it can be assumed that these two arterials would normally carry the highest traffic volumes within the city. Similarly, since Duarte Road, Foothill Boulevard, Mountain Avenue, California Avenue south of Huntington Drive are all designed as secondary arterials, it can further be assumed that notable traffic volumes may exist on these facilities.
- **Duarte (**Figure 6-13**)** – The busiest arterials within Duarte are Huntington Drive and Mountain Avenue near the I-210. In 2005, which represents the latest data available, Huntington Drive was estimated to carry between 24,000 and 29,000 vehicles per day within the city limits, while the sections of Mountain Avenue immediately north and south of the I-210 carried 24,500 and 31,000 vehicles respectively. Other arterials typically had 24-hour volumes of less than 15,000 vehicles, except for a section of Buena Vista close to the I-210 with a daily volume of nearly 19,000 vehicles.
- **Jurisdictions east of I-605 (**Figure 6-13**)** – East of the I-605, the two primary east-west arterial corridors are Foothill Boulevard / Alosta Avenue and Arrow Highway. Both corridors typically carry between 20,000 and 25,000 vehicles day. The three primary north-south arterials are Irwindale Avenue, Grand Avenue, and Lone Hill Avenue. The three arterials all feature sections carrying over 30,000 vehicles per day. Azusa Road and Citrus Avenue are two additional relatively busy arterials.

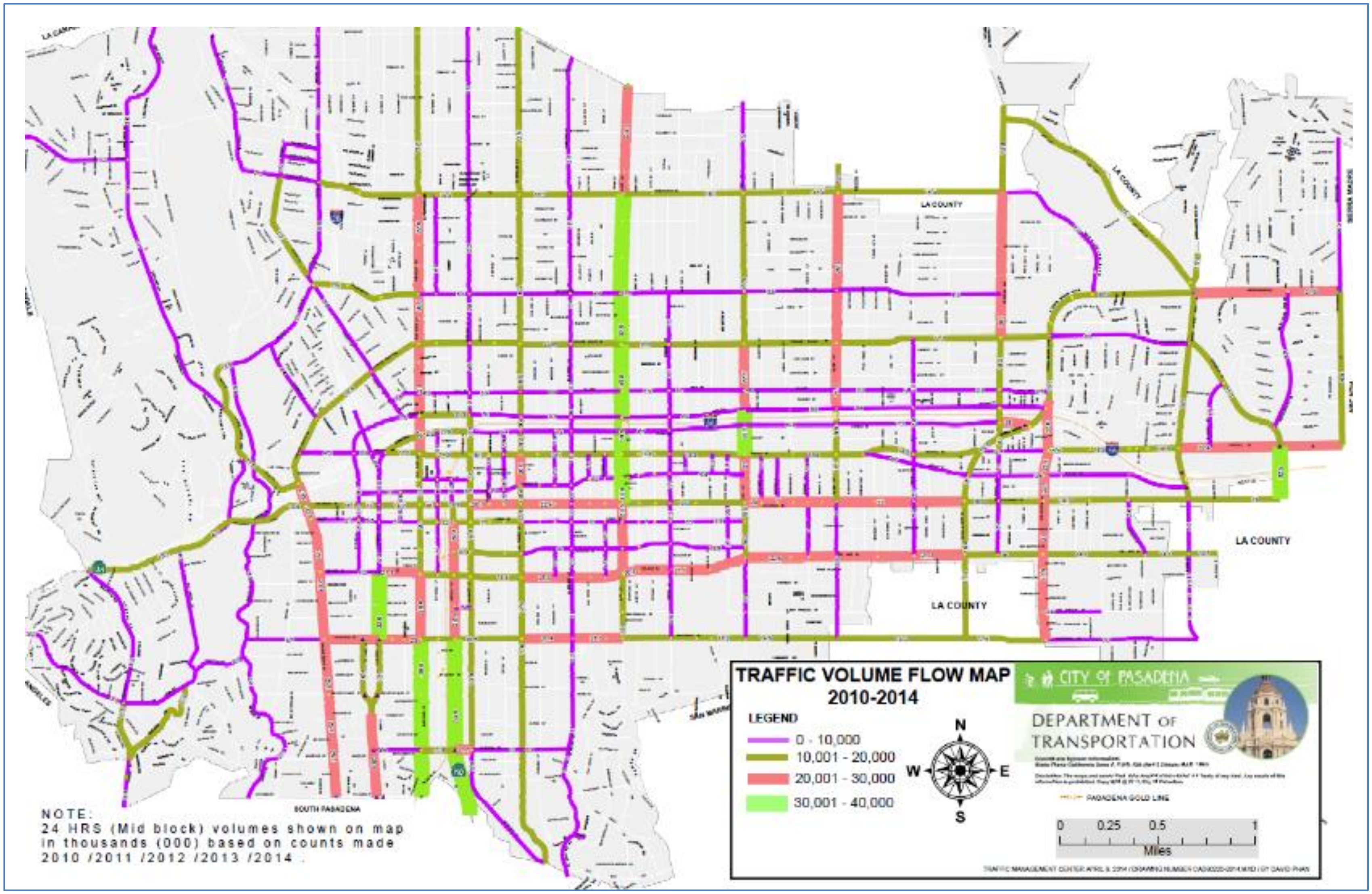


Figure 6-11 – 24-Hour Arterial Traffic Volumes, Pasadena (2010-2014)

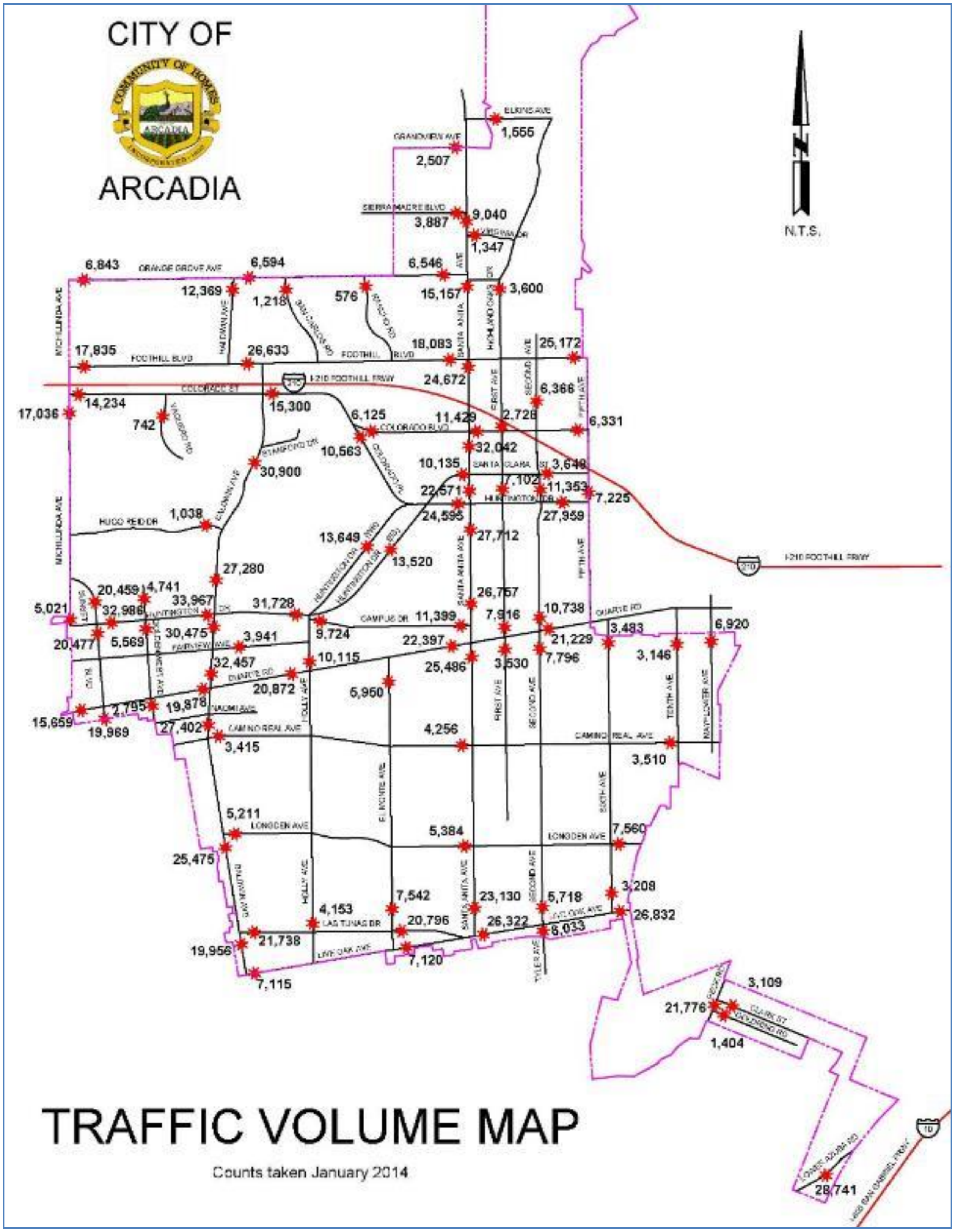


Figure 6-12 – 24-Hour Arterial Traffic Volumes, Arcadia (2014)

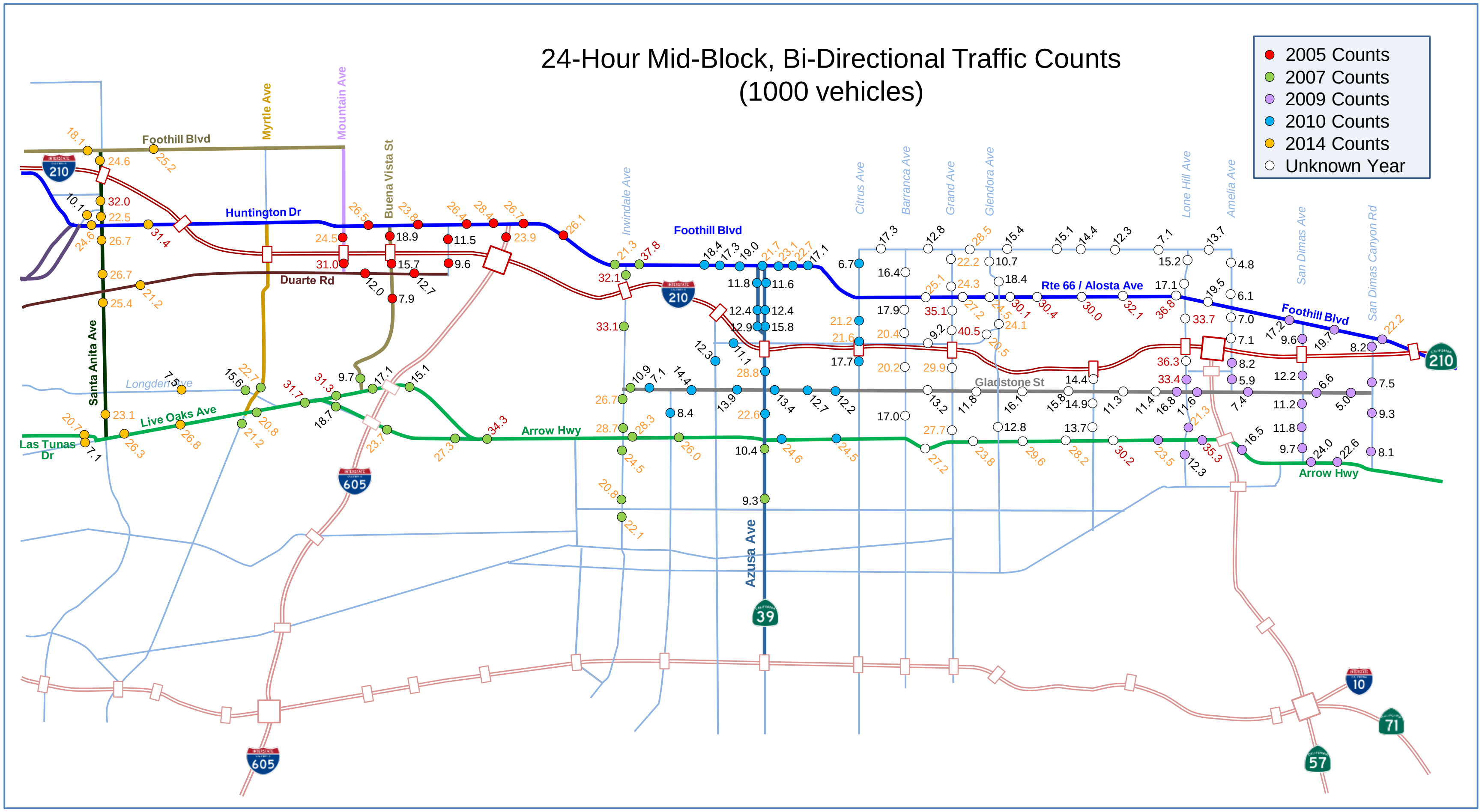


Figure 6-13 – 24-Hour Arterial Traffic Volumes, East End of Corridor

6.1.3.2. Arterial Truck Volumes

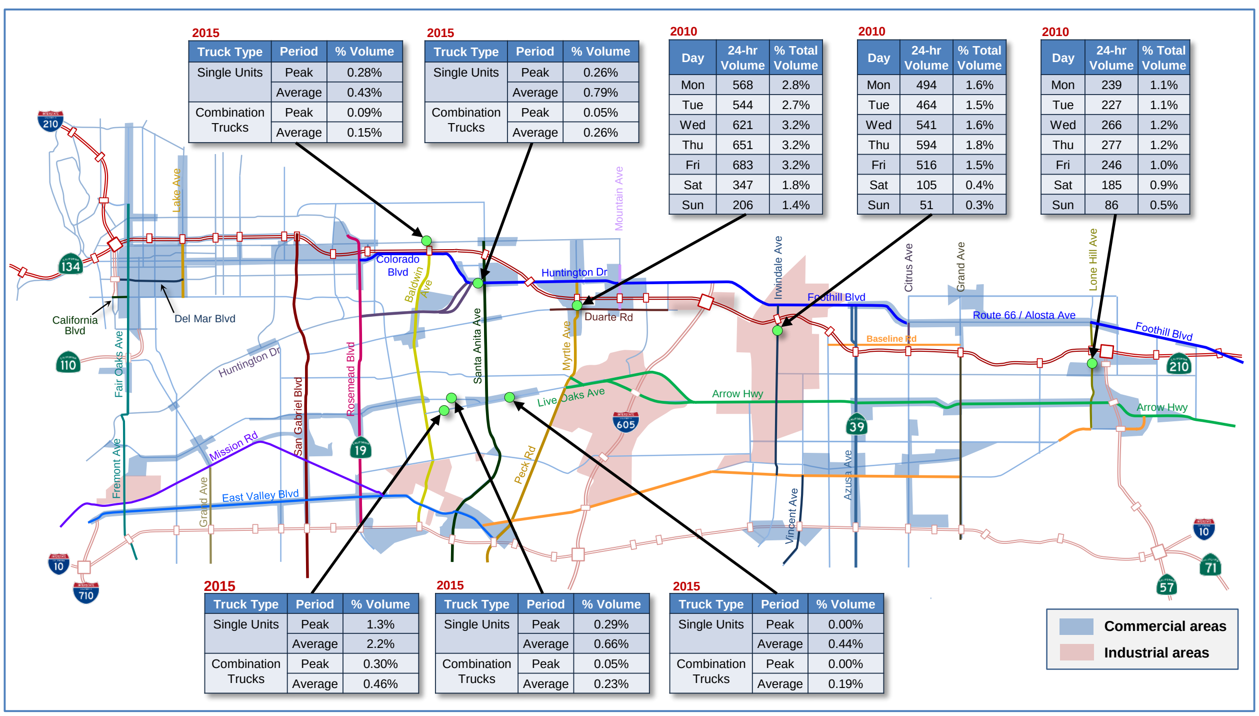
Figure 6-14 maps the results of several vehicle classification counts that were conducted within the I-210 corridor to assess the proportion of trucks traveling on specific roadway segments. This information is derived from the following two sources:

- 2010 study on truck movements that was commissioned by Metro
- 2015 vehicle classification counts commissioned by the City of Arcadia.

At each location, the illustrated statistics indicate the proportion of heavy-duty trucks, typically vehicles with three axles or more, that were observed within the general traffic. The arterial segments drawn with a wider line further represent segments that were included in Metro's Countywide Strategic Truck Arterial Network (CSTAN), while the shaded areas respectively indicate commercial and industrial areas.

Based on the information presented in Figure 6-14 and in the report produced for Metro's 2010 truck movement study, the following key observations can be made:

- The proportion of heavy-duty trucks traveling on corridor arterials is relatively small. Across the count locations, heavy-duty trucks comprised 3% or less of all observed vehicles.
- Reflective of business cycles, higher proportions of trucks are typically observed during weekdays, with activity peaks on Wednesdays or Thursdays.
- No significant truck traffic is expected on arterial segments not designed as a truck route, mainly because law enforcement agencies can give citations to truckers using these segments without a permit or valid reason.
- The largest proportions of trucks are typically observed on arterials connecting large industrial areas with the I-210, I-605 and I-10 freeways.



2015

Truck Type	Period	% Volume
Single Units	Peak	0.28%
	Average	0.43%
Combination Trucks	Peak	0.09%
	Average	0.15%

2015

Truck Type	Period	% Volume
Single Units	Peak	0.26%
	Average	0.79%
Combination Trucks	Peak	0.05%
	Average	0.26%

2010

Day	24-hr Volume	% Total Volume
Mon	568	2.8%
Tue	544	2.7%
Wed	621	3.2%
Thu	651	3.2%
Fri	683	3.2%
Sat	347	1.8%
Sun	206	1.4%

2010

Day	24-hr Volume	% Total Volume
Mon	494	1.6%
Tue	464	1.5%
Wed	541	1.6%
Thu	594	1.8%
Fri	516	1.5%
Sat	105	0.4%
Sun	51	0.3%

2010

Day	24-hr Volume	% Total Volume
Mon	239	1.1%
Tue	227	1.1%
Wed	266	1.2%
Thu	277	1.2%
Fri	246	1.0%
Sat	185	0.9%
Sun	86	0.5%

2015

Truck Type	Period	% Volume
Single Units	Peak	1.3%
	Average	2.2%
Combination Trucks	Peak	0.30%
	Average	0.46%

2015

Truck Type	Period	% Volume
Single Units	Peak	0.29%
	Average	0.66%
Combination Trucks	Peak	0.05%
	Average	0.23%

2015

Truck Type	Period	% Volume
Single Units	Peak	0.00%
	Average	0.44%
Combination Trucks	Peak	0.00%
	Average	0.19%

Figure 6-14 – Observed Arterial Truck Volumes

6.2. FREEWAY OPERATIONS

This section describes key aspects of current traffic operations along the I-210 freeway. Elements characterized herein include:

- Location and cause of recurring bottlenecks
- Observed vehicle delays
- Current travel time profiles
- Current travel time reliability
- Location of safety hotspots

6.2.1. RECURRING BOTTLENECKS

Figure 6-15 and Figure 6-16 identify the main recurring bottlenecks associated with the AM and PM peak travel periods along the I-210 freeway. These bottlenecks were identified and verified during the winter of 2007 and spring of 2008 by the team that developed the I-210 Corridor System Management Plan (CSMP). The bottlenecks were identified based on data from Caltrans' 2006 State Highway Congestion Monitoring Program (HICOMP) Annual Data Compilation report, probe vehicle runs, Caltrans freeway detector data, aerial photos, field reviews, and other data sources. As indicated, most of the bottlenecks along the freeway are associated with locations with significant weaving traffic, either by traffic entering or exiting the freeway, and in some cases compounded by roadway geometry factors, such as sharp curves or lane drops.

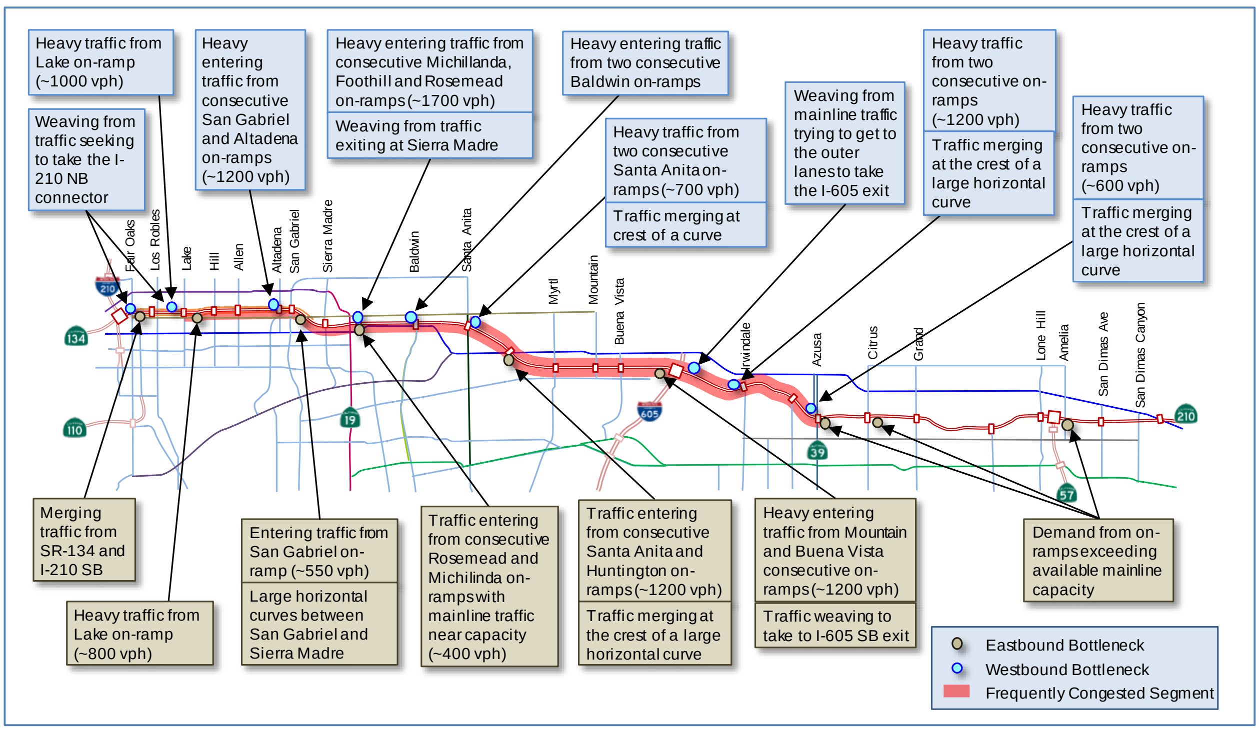


Figure 6-15 – Main Freeway Bottlenecks – AM Peak

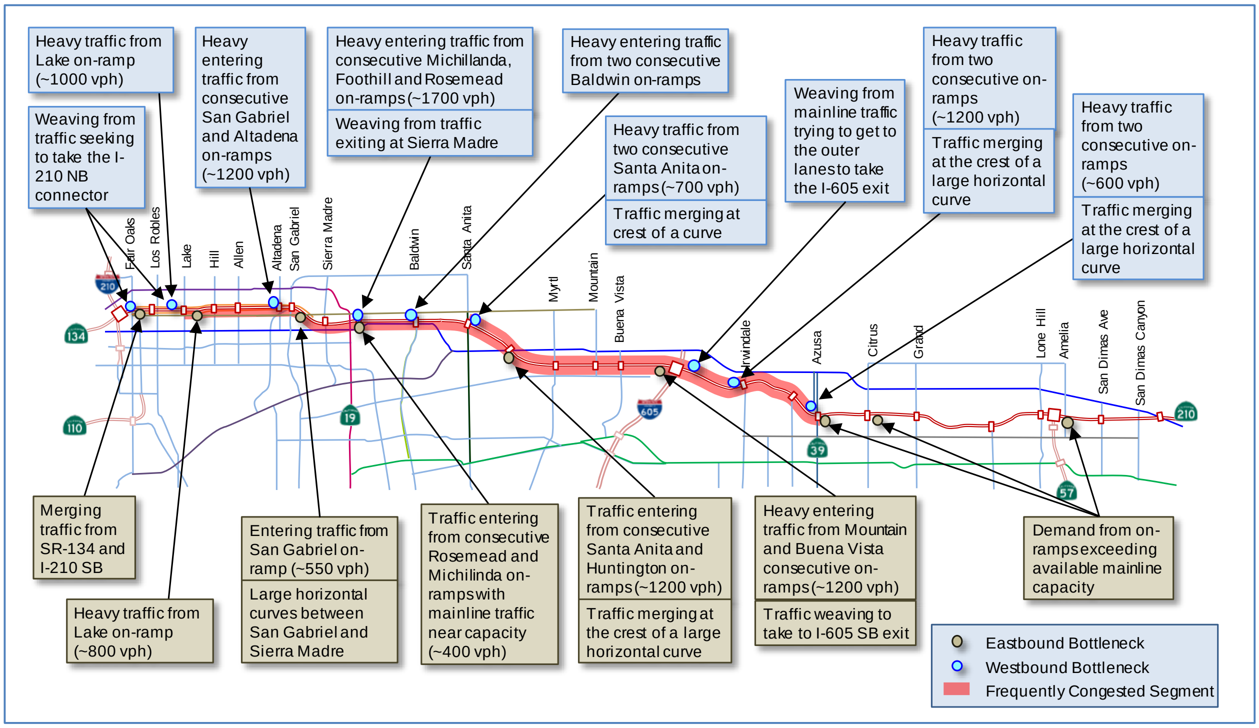


Figure 6-16 – Main Freeway Bottlenecks – PM Peak

In each direction, the bottlenecks on the HOV lane typically occur at the same location as the bottlenecks on the freeway mainline. This is primarily due to the close proximity of the HOV lane to the mainline traffic lanes. Along the I-210, the HOV lane is separated from the mainline lanes by a simple double yellow-and-white stripe separation about two feet in width. The HOV-lane also has little to no inside shoulder. When stop and go traffic occurs on the mainline, traffic on HOV lane also slows down, primarily out of caution, thus resulting in a flow breakdown, particularly near the HOV lane ingress/egress locations and at roadway curves.

6.2.2. AVERAGE DAILY TRAVEL TIME PROFILES

Figure 6-17 illustrates travel time profiles characterizing the traffic conditions that were experienced by motorists at different times of the day on different weekdays between September 14 and October 12, 2014 when traveling between the Arroyo Boulevard interchange in Pasadena (Exit 22B) and the Foothill Boulevard interchange in La Verne (Exit 47). The illustrated travel times are not direct observations, but estimated averages based on 5-minute speed data that were derived by PeMS from loop occupancy and count data obtained from mainline traffic sensors along the I-210.

Considering that it would take a vehicle 23.03 minutes to travel the section of I-210 under evaluation at a constant speed of 65 mph, the following observations can be made from the illustrated data:

- In the westbound direction during weekdays, motorists experience increased travel time on each morning between 6:00 AM and 11:00 AM, as well as between 4:00 and 8:00 PM in the afternoon. The morning travel time typically peaks between 7:00 and 9:00 AM, at around 45 minutes on Mondays, Tuesdays and Wednesdays, and at around 35 minutes on Thursdays and Fridays. In the afternoon, weekday travel times generally remain below 26 minutes, except on Fridays, when the average travel time along I-210 reaches 30 minutes between 6:00 PM and 7:00 PM.

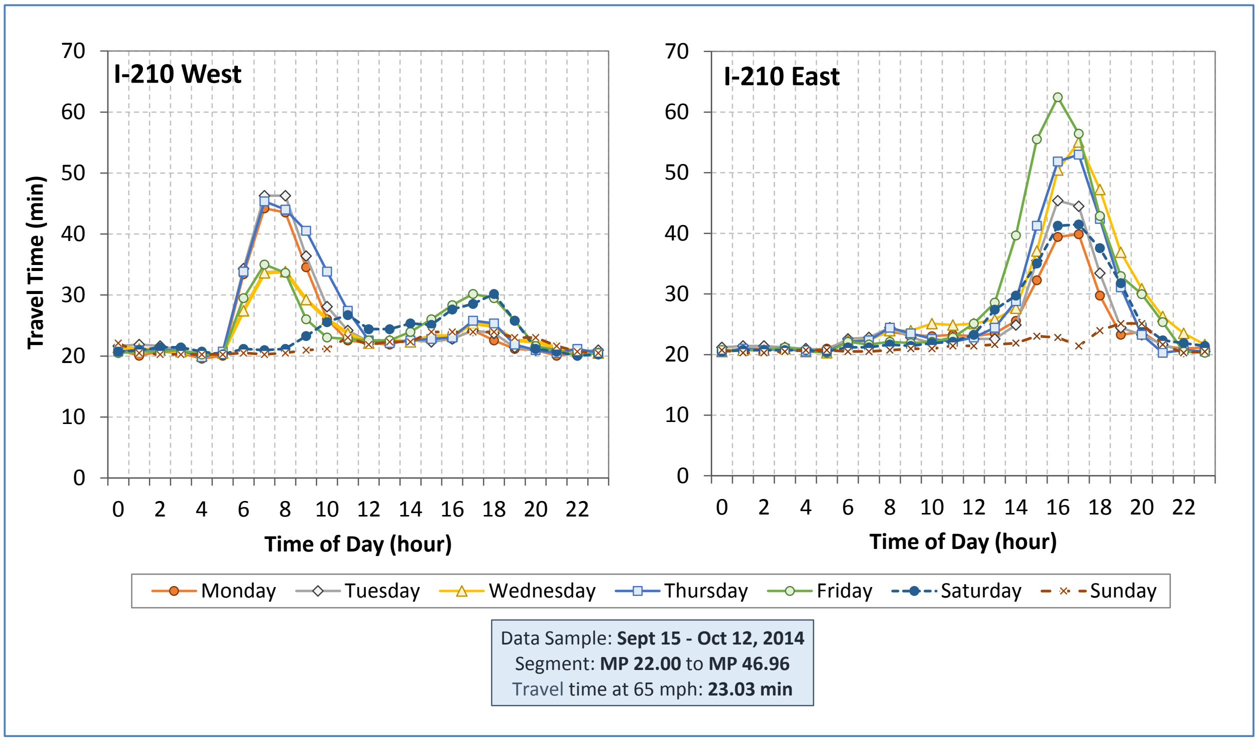


Figure 6-17 – Average Travel Times on I-210 by Time of Day, Day of Week, and Direction

- In the eastbound direction during weekdays, travelers only experience significantly longer travel times during the afternoon, particularly between 3:00 PM and 7:00 PM. Travel times typically peak between 4:00 PM and 6:00 PM, at 38 minutes on Monday, 45 minutes on Tuesdays, around 53 minutes on Wednesdays and Thursdays, and around 63 minutes on Friday.
- Increased travel times are also observed on Saturday afternoons in both directions. In the westbound direction, travel times peak at around 30 minute between 6:00 PM and 7:00 PM. In the eastbound direction, the peak travel time is observed to oscillate around 42 minutes between 4:00 PM and 6:00 PM.
- On Sundays, the average travel times remain below 28 minutes, as traffic on the freeway is relatively light throughout the day.

6.2.3. DAILY TRAVEL TIME RELIABILITY

Figure 6-18 characterizes the variability of travel times along I-210 across weekdays for each direction. Similar to Figure 6-17, this characterization is based on estimated traffic speeds derived by PeMS from data collected from mainline freeway traffic detectors over a four-week period between September 15 and October 12, 2014. This is a period with no major holiday.

For each weekday and travel direction, the figure illustrates the average estimated travel time between the Arroyo Boulevard interchange in Pasadena (Exit 22B) and the Foothill Boulevard interchange in La Verne (Exit 47) for each one-hour interval. The travel times corresponding to one standard deviation from the mean and the 5th and 95th percentiles travel times are also shown. The one standard deviation range illustrates the shortest and fastest travel times that would include 68% of observations if assumed that

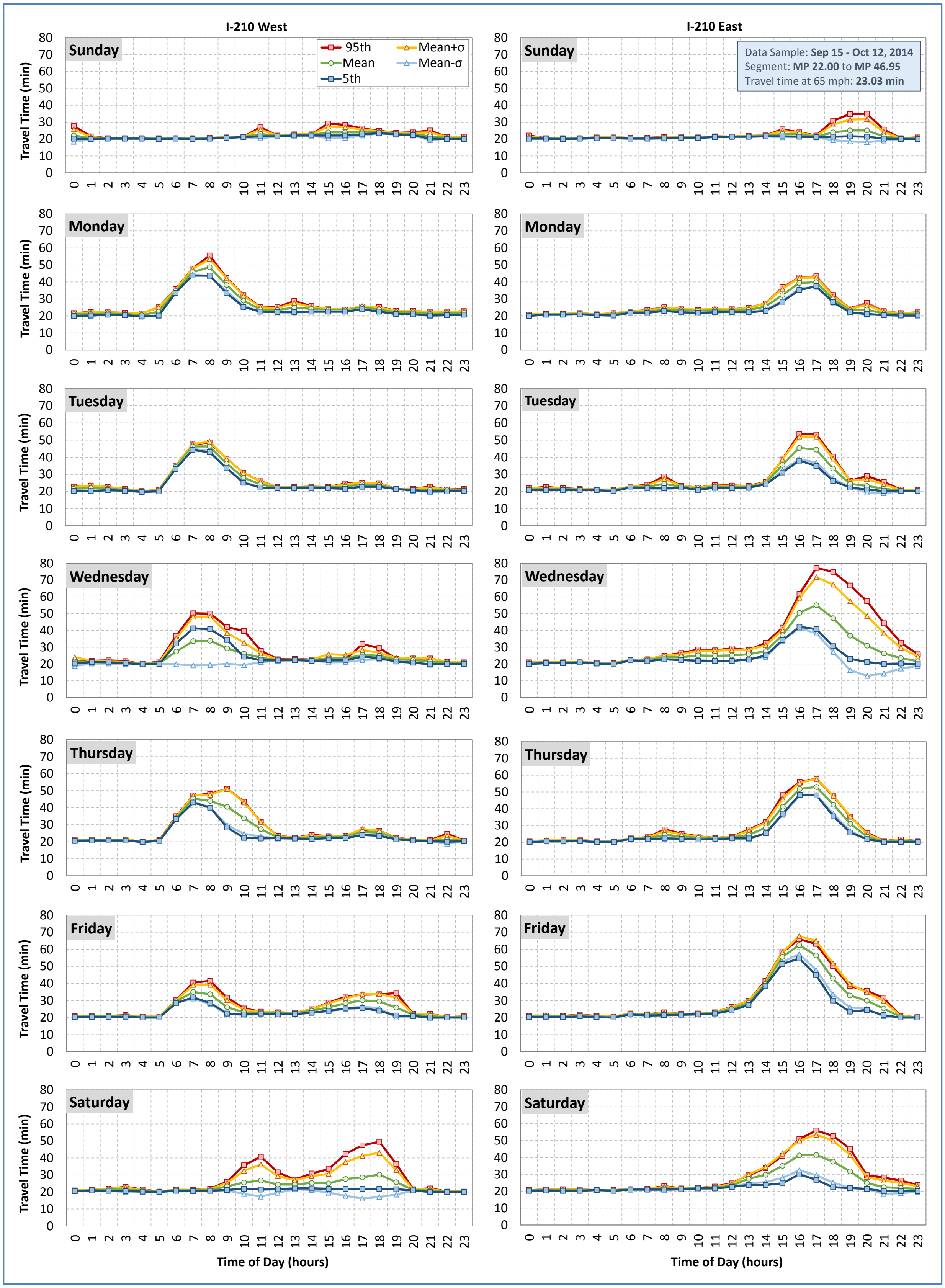


Figure 6-18 – Variability of Travel Times on I-210 by Time of Day, Day of Week, and Direction

travel times are normally distributed. The 5th and 95th percentiles further represent extreme values that may be observed on occasion. While longer travel times are possible, the 5th and 95th percentile boundaries are thought to represent a reasonable balance between extreme traffic conditions and conditions that can be expected to occur during typical operations.

As shown in the figure, travel times along the I-210 exhibit significant variability, both within each day and across days. The following are key observations on travel times that can be made from the data:

- Since there is no holiday in the data sample, fluctuations in traffic demand from one week to the next and variations in the number, duration, and impact of incidents occurring on the freeway are the likely primarily factors influencing the variations in travel times.
- In the westbound direction, the start of the AM peak period generally occurs at the same time across weekdays, between 6:00 and 7:00 AM. In the eastbound direction, depending on the day considered, the afternoon peak period starts in either the 1:00 to 2:00 PM, 2:00 to 3:00 PM, or 3:00 to 4:00 PM interval.
- For a given interval, there can be significant variations in travel times from one week to the next, particularly during peak periods. Within the illustrated sample, Wednesday afternoon travel times have the widest variations, with a range of nearly 40 minutes between the 5th and 95th percentile travel times. This appears to be the results of incidents. While smaller variations are generally observed for other days, several periods still feature ranges of 10 to 20 minutes.
- Across weekdays, there is significant variations in the magnitude of the AM peak and PM peak congestion. For the PM peak period, for instance, the average eastbound travel time over the sampling period reaches 40 minutes on Monday, 46 minutes on Tuesday, 55 minutes on Wednesday, 53 minutes on Thursday, and 62 minutes on Friday. This is a range of 22 minutes. For the AM peak period, peak travel times in the westbound direction similarly vary between 33 and 48 minutes, for a range of 15 minutes.
- In addition to the magnitude of the congestion, the duration of the peak period on a given weekday can vary noticeably from one weekday to the next.
- Fluctuations during peak periods result in a travel time index ranging between 0.04 and 0.58. In the off-peak period, the index generally oscillates between 0.01 and 0.20, with an average of 0.05. The travel time index represents the additional time that must be budgeted above the reported average travel time to ensure an on-time arrival 95% of the time. As an example, an index of 0.35 associated to a 40-minute average travel time period indicates that a motorist should plan for an additional 14 minutes of travel, or a potential total travel time of 54 minutes, to ensure an on-time arrival 95% of the time.
- Over the weekend, travel times exhibit significant variability in both directions on Saturday afternoon, likely due to variations in shopping and other leisure activity traffic. Increased variability is also observed on Saturday morning in the westbound direction and on Sunday evening in the opposing direction, likely due to outbound and inbound weekend traffic.

6.2.4. INCURRED DELAYS

Figure 6-19 illustrates the average weekday delay incurred by vehicles traveling along different sections of I-210. For each travel direction, the figure illustrates the average daily total vehicle delay for non-holiday weekdays from January to December 2014. The delays were calculated by PeMS based on vehicle

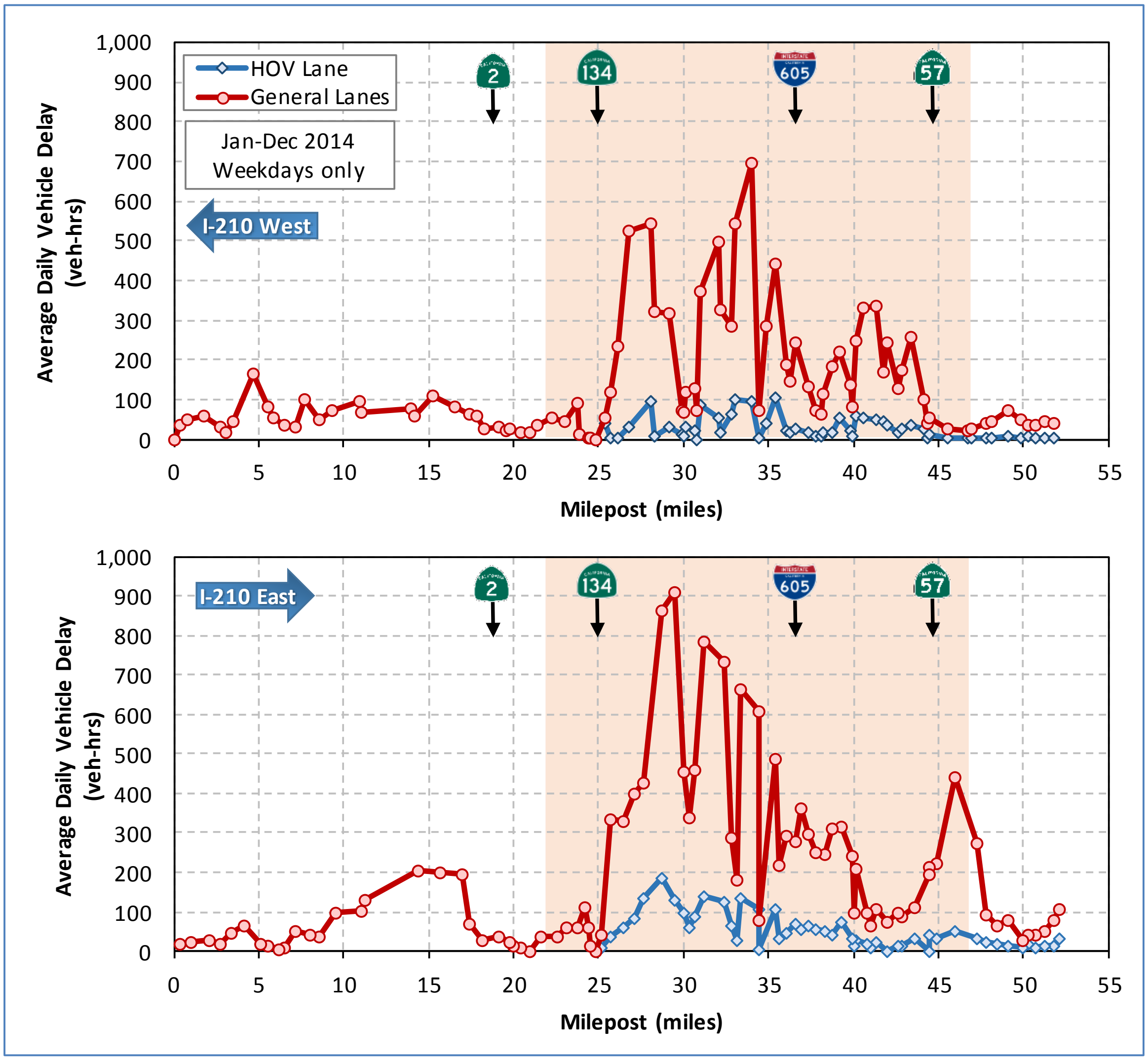


Figure 6-19 – Average Weekday Vehicle Delay at Various Locations along I-210

counts and speed estimates from traffic detectors along the freeway mainline and HOV lanes using a reference free-flow speed of 60 mph. Reflective of the higher local traffic levels, most of the delays are incurred between the SR-134 and SR-57 interchanges, with westbound peaks around Sierra Madre Boulevard (Exit 29A) and Myrtle Avenue (Exit 34), and eastbound peaks around Sierra Madre Villa Avenue (Exit 29B) and San Dimas Avenue (Exit 45). Outside of this section, notable delays are also observed in the eastbound direction upstream of the SR-2 interchange. Significant variability further exists from one detection station to the next as traffic moves from one bottleneck to the next.

Figure 6-20 tracks the changes in average weekday delay along both directions of I-210 from January 2008 to December 2014. Following significant fluctuations, delays in the westbound direction are 25% higher in 2014 than in 2008, while the eastbound delays are 41% higher, indicating a significant increase in congestion. Various factors may explain the significant fluctuations observed between 2008 and 2013. The financial crisis of late 2008 and subsequent economic recession provide some explanations. Construction projects, along either I-210 or neighboring freeways, may have also influenced travel demand, as suggested in the VMT analysis of Figure 4. Infrastructure and operational improvements,

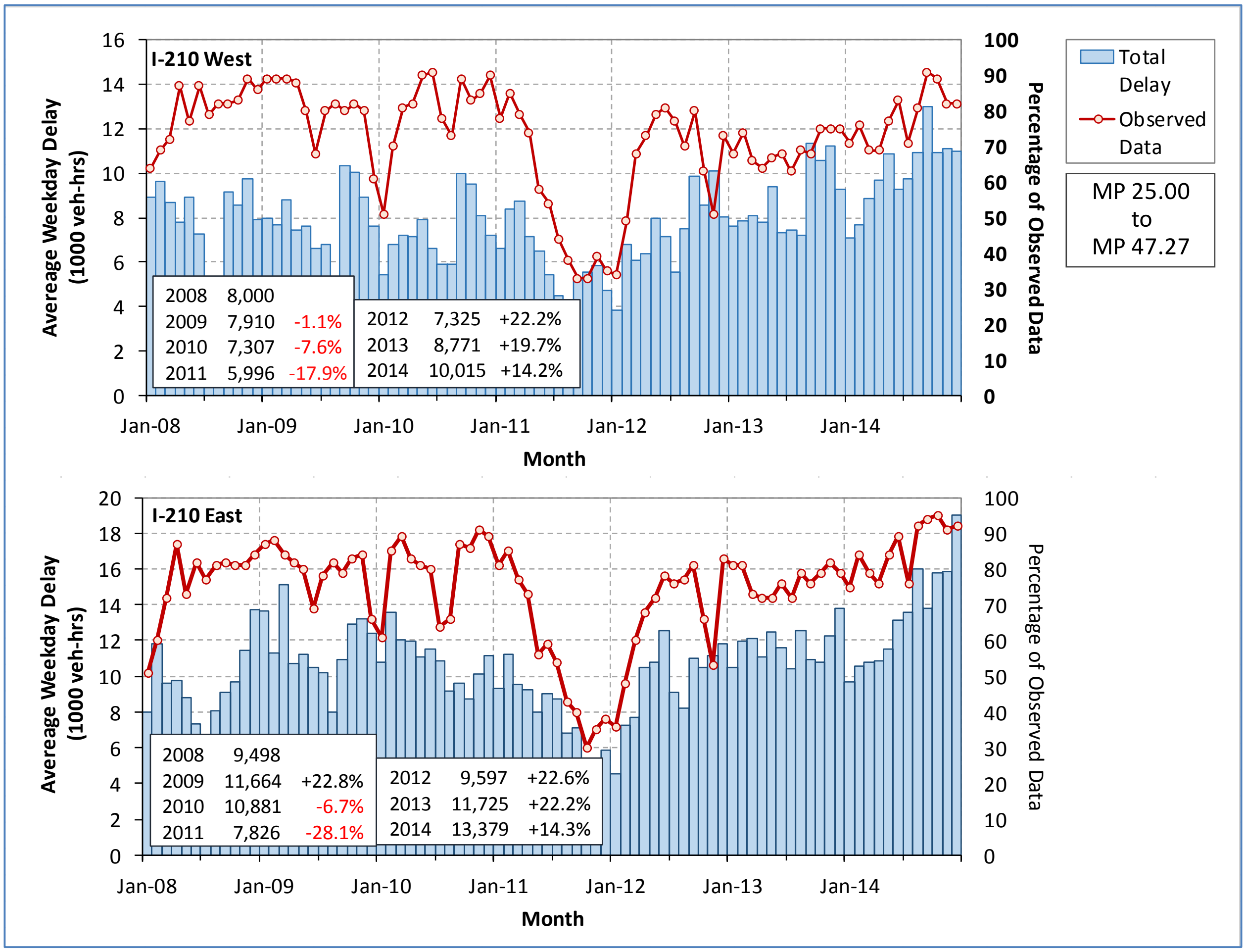


Figure 6-20 – Average Weekday Vehicle Delay between MP 25.00 and MP 46.94, by Month

such as the activation of I-605/I-210 connector metering and the addition in early 2008 of ramps meters at non-metered ramps and on HOV bypass lanes on metered ramps as part of the I-210 Congestion Relief Project, are likely additional influencing events. Finally, some fluctuations such as the large drop in estimated delays in late 2011/early 2012 may be explained by data quality issue, as evidenced by the in the percentage of observed data matching the period with reduced delays.

Figure 6-21, finally, compares the average incurred delay in each direction of travel for each day of the week. For the eastbound direction, the lowest delays are typically observed on Monday and noticeably increase with each passing day until a peak is reached on Friday. This trend reflects the trend of increasing VMT from one weekday to the next that was presented in Figure 5. For the westbound direction, the data indicates that traffic experiences relatively constant congestion levels from Monday, Tuesday and Wednesday, higher delays on Thursday, and noticeably lower congestion on Fridays. This is somewhat counterintuitive with the data of Figure 5 that shows an increase in VMT as the week progresses. This may be the result of a slightly lower overall traffic demand in the eastbound direction.

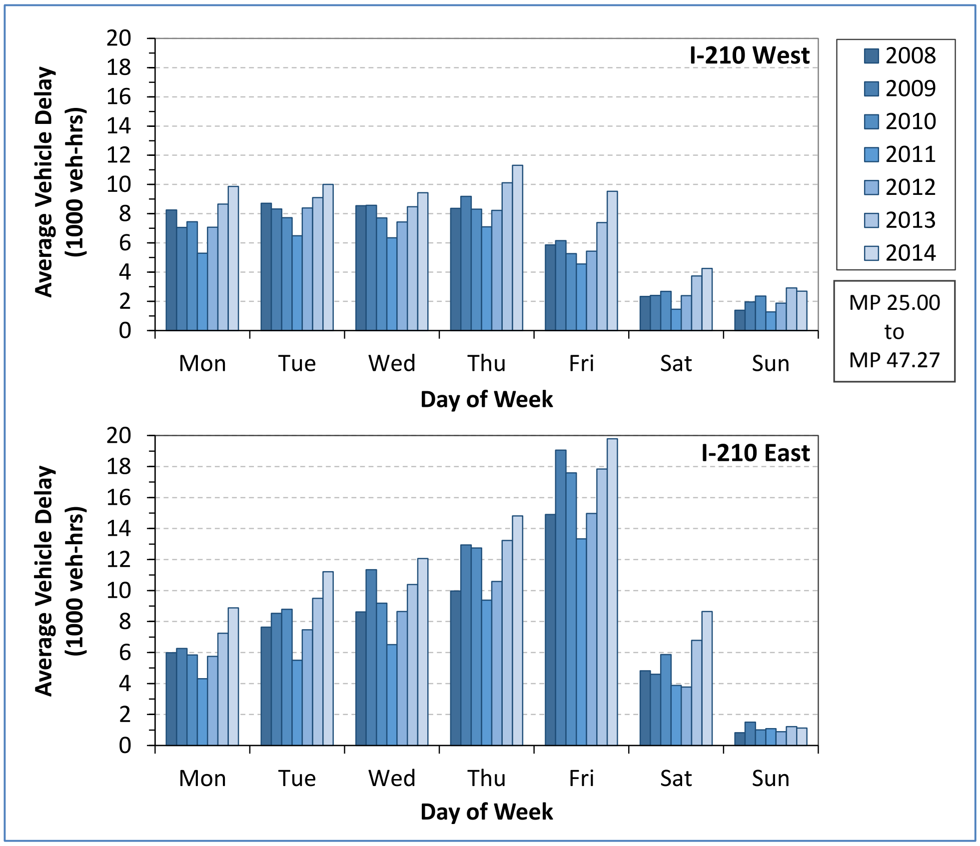


Figure 6-21 – Average Daily Vehicle Delay between MP 25.00 and MP 46.94, by Day of Week

6.2.5. TRAFFIC SAFETY

This section presents a general safety assessment of the I-210 corridor. This assessment aims to characterize general accident trends along the corridor and to highlight locations with notable accident concentrations and readily apparent patterns. It is not intended to supplant more detailed safety investigations routinely performed by Caltrans staff.

Table 6-4 begins by presenting general statistics on incidents that have been logged by the CHP along various sections of I-210 within Los Angeles County throughout 2013, based on information available in PeMS. The statistics cover both injury and non-injury data (excluding fatal accidents), as well as incidents ranging in duration from less than one minute to several hours. Data from 2013 are presented since this was the most recent year for which a nearly complete set of incident records was available at the time of the study. The top part of the table presents average statistics for normal weekdays while the bottom section presents statistics for weekend days and weekdays falling on a holiday.

The data in Table 6-4 indicate that nearly 29 incidents were logged on average every weekday throughout 2013 along the section of I-210 traversing Los Angeles County. Over the same period, over 14 incidents were additionally logged daily on average on weekends and holidays. When considering only the section between SR-134 and SR-57, where most of the congestion is located, approximately 18 incidents were logged daily on average during weekdays, while 16 incidents were logged daily during weekends or holidays. These frequencies indicate that days without incidents along I-210 are rare.

Table 6-4 – Frequency and Rate of Incidents on I-210 in 2013

Corridor Section			I-210 W				I-210 E			
Segment	Mileposts	Length	Number of Incidents	Vehicle-miles traveled (VMT)	Incidents/ Day	Incidents/ million VMT	Number of Incidents	Vehicle-miles traveled (VMT)	Incidents/ day	Incidents/ million VMT
Weekdays										
I-5 to SR-134	0.0 – 25.0	25.0	1,070	353,740,681	4.3	3.0	1,023	343,691,191	4.1	3.0
SR-134 to Rosemead	25.0 – 30.0	5.0	594	183,507,565	2.4	3.2	574	166,852,100	2.3	3.4
Rosemead to I-605	30.0 – 36.6	6.6	687	198,798,042	2.7	3.5	844	190,392,364	3.4	4.4
I-605 to SR-57	36.6 – 45.0	8.4	921	233,367,616	3.7	3.9	807	246,826,066	3.2	3.3
SR-57 to Foothill	45.0 – 47.3	2.3	107	42,277,015	0.4	2.5	93	44,015,890	0.4	2.1
Foothill to County Line	47.3 – 52.5	5.2	216	94,664,611	0.9	2.3	260	104,062,683	1.0	2.5
Freeway	***0.0 – 52.5***	***52.3***	3,604	1,106,355,531	14.4	3.3	3,614	1,095,840,293	14.5	3.3
Weekends and Holidays										
I-5 to SR-134	0.0 – 25.0	25.0	260	114,966,583	2.3	2.3	275	112,682,010	2.4	2.4
SR-134 to Rosemead	25.0 – 30.0	5.0	106	68,533,962	0.9	1.5	135	63,405,013	1.2	2.1
Rosemead to I-605	30.0 – 36.6	6.6	145	79,085,821	1.3	1.8	181	75,624,105	1.6	2.4
I-605 to SR-57	36.6 – 45.0	8.4	196	93,873,041	1.7	2.1	171	97,601,231	1.5	1.8
SR-57 to Foothill	45.0 – 47.3	2.3	29	17,071,627	0.3	1.7	22	18,334,183	0.2	1.2
Foothill to County Line	47.3 – 52.5	5.2	53	38,407,221	0.5	1.4	74	41,335,997	0.6	1.8
Freeway	***0.0 – 52.5***	***52.5***	789	411,938,254	6.9	1.9	862	408,982,540	7.5	2.1

Source: All Non-injury and injury accidents reported by PeMS from CHP incidents data

The following analysis considers the rate of incidents relative to traffic demand, as expressed by the number of incidents per million miles traveled. For this metric, Table 6-4 indicates that 3.3 incidents per million miles traveled were logged on average during weekdays throughout 2013 over the entire section of I-210 traversing Los Angeles County, while 2.0 incidents were logged over weekend days and holidays. In the westbound direction, the section with the highest accident rate is the section running from SR-57 to I-605, with 3.9 incidents per million miles traveled. In the opposite direction, the section between Rosemead and I-605 has the highest incident rate, with 4.4 incidents per million miles traveled. This is not surprising given that both sections features high traffic demand and several bottlenecks. Weekday incident rates on other sections vary between 2.1 and 3.5. Over weekends and holidays, the section between I-5 and SR-134 has the highest incident rate, with 2.3 incidents per million miles traveled in the westbound direction and 2.4 in the opposite direction.

Figure 6-22 maps in more detail the location of incidents along I-210. The figure compiles the number of incidents that have been reported for each travel direction on the freeway mainline and ramps throughout 2013 over successive, non-overlapping 0.25-mile sections. As can be observed, the freeway sections with the highest occurrence of incidents are predominantly located between the SR-134 and SR-57 interchanges. High-incident sections are more specifically associated with the Sierra Madre Boulevard/San Gabriel Boulevard (PM 28.25-28.50), Baldwin Avenue (PM 31.25-31.50), Huntington Drive (PM 32.75-33.25), Myrtle Avenue (PM 34.00-34.25), I-605 (PM 36.25-36.75), Irwindale Avenue (PM 37.50-38.00), Azusa Avenue (PM 39.50-39.75), and SR-57 (PM 40.25-40.75) interchanges. Many of these sections are also closely linked to freeway bottlenecks (see Figure 6-15 and Figure 6-16 in Section 6.2.1). While some variations exist in the number of reported incidents from year to year, a multi-year data analysis further reveals a relative consistency in the location of the high-incident sections.

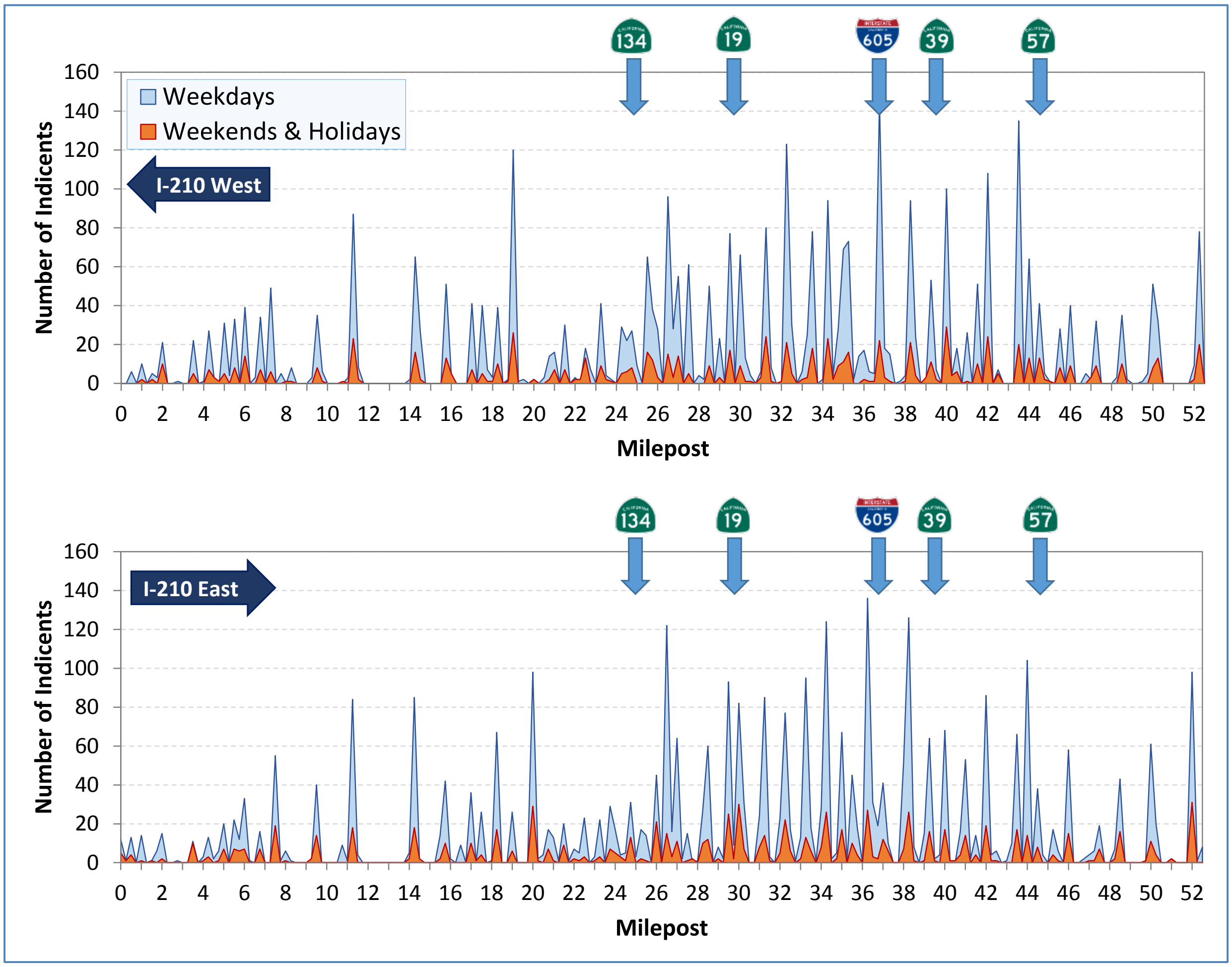


Figure 6-22 – Location of CHP Reported Incidents along I-210 in 2013

Figure 6-23 presents contour plots illustrating when and where incidents tend to occur along I-210 between SR-134 and SR-57. The highest frequencies are generally associated with major interchanges. As further expected, peak frequencies are also associated with peak travel periods and directions. During weekdays, incidents tend to occur in westbound direction in the morning, and in the eastbound direction in the afternoon. Less noticeable peaks are observed for weekend days and holidays due to the lower traffic demand that prevails on those days. In this case, the highest incident frequencies are associated with the late morning or afternoon period, when traffic demand normally reaches its maximum level.

Figure 6-24 looks at the duration of events between SR-134 and Foothill Boulevard. These events are the same as those mapped in Figure 6-23. It should be noted that the actual duration of events is in many cases likely to have been longer than reported. Many of the CHP incident records that were used to perform the compilation have a duration that corresponds to the time it took to notify the CHP or for a vehicle to arrive at the scene, not the time to clear the event. The records also provide no information about the extent to which traffic was affected on the freeway, such as how many lanes were closed and for how long. The compilation nevertheless shows the frequency of incidents with noticeable impacts on local traffic. For instance, 768 events lasting one hour or more were recorded throughout 2013, with 182 of these events lasting more than 2 hours. Of these events, 621 occurred during weekdays and 147 during weekends or holidays. These statistics convert to 2.48 events lasting one hour or more occurring every weekday on average, and 1.28 events occurring every weekend or holiday day.

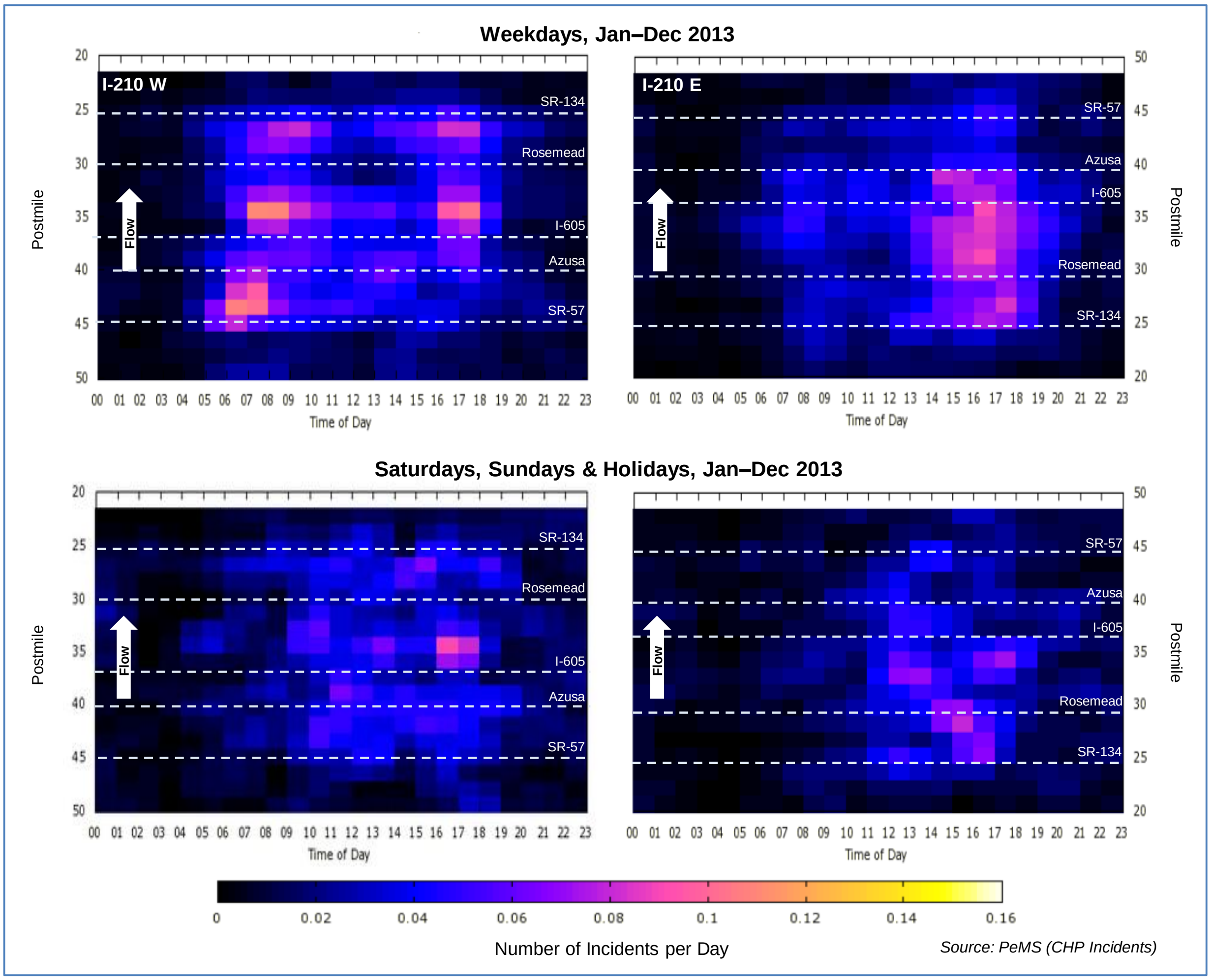


Figure 6-23 – Frequency of Incidents along I-210 According to Time of Day in 2013

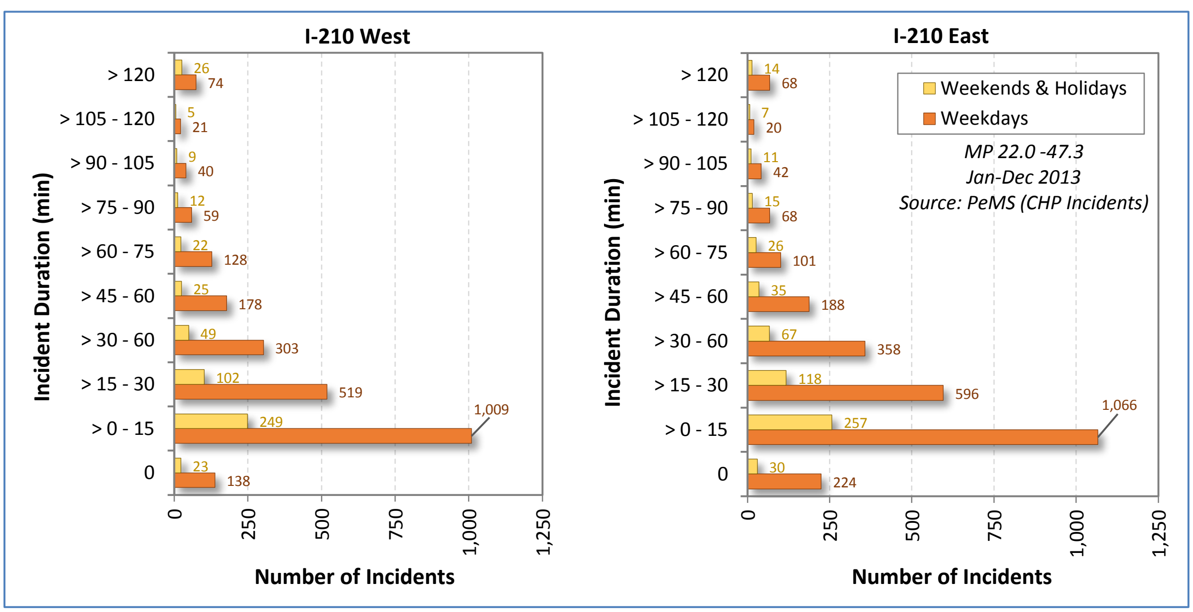


Figure 6-24 – Incident Durations along I-210 between SR-134 and Foothill Boulevard in 2013

Table 6-5 – 2011 Incidents with Caltrans Traffic Management Team Dispatch in 2014

Date	Day	Milepost	Direction	Time of Occurrence	Duration	Jurisdiction	Location	Description	Delay (veh-hrs)
I-210 / I-5 to SR-134									
2/15	Sat	0.84	EB	12:07	8:38	Los Angeles	Yarnell St	Fatal accident	437
2/26	Wed	22.4	WB	3:00	4:40	Pasadena	Arroyo Parkway	Fatal accident	2,177
2/26	Wed	24.7	EB	23:36	5:39	Pasadena	I-210 Connector	Accident with 4 big rigs, 1 overturned	369
2/27	Thu	24.59	EB	23:38	4:25	Pasadena	I-210 Connector	Jackknifed big rig	309
2/28	Fri	4.11	EB	17:46	2:01	Los Angeles	Maclay St	Jackknifed big rig	607
3/12	Wed	7.6	EB	22:28	5:22	Los Angeles	Osborne to Wheatland	Emergency bridge work	0
3/14	Fri	2.1	WB	0:57	3:43	Los Angeles	Roxford St	Murder investigation	706
4/2	Wed	25.1	EB	1:59	6:31	Pasadena	I-210 Connector	Accident involving 3 big rigs	1,621
5/19	Mon	12.5	EB	13:38	1:25	Los Angeles	Sunland Blvd	Brush fire	1,819
6/4	Wed	13	WB	10:41	8:24	Los Angeles	La Tuna Canyon Rd	Big rig into center divider	11,143
6/11	Wed	9.08	EB	15:02	3:35	Los Angeles	Wheatland	Jackknife and diesel spill	9,216
7/23	Wed	10.7	WB	5:29	12:21	Los Angeles	Sunland Blvd	Big rig fire	6,848
9/16	Tue	16.5	EB	10:33	4:19	Glendale	Pennsylvania	Emergency slab repair	0
9/23	Tue	10.9	EB	8:06	2:33	Los Angeles	Sunland Blvd	Grenade on freeway	1,724
10/28	Tue	16.8	EB	22:54	8:21	Glendale	Pennsylvania Ave	Overturned big rig	2,067
11/23	Sun	0.4	WB	19:47	3:08	Pasadena	SB I-5 Connector	Big rig accident	99
11/25	Tue	0.5	WB	8:44	1:56	Pasadena	SB I-5 Connector	Guardrail repair	92
I-210 / SR-134 to I-605									
2/27	Thu	24.5	WB	0:42	3:08	Pasadena	EB SR-134 Connector	Jackknifed big rig	142
3/16	Sun	25.3	WB	6:50	3:50	Pasadena	WB I-210 Connector	Emergency closure to repair water main	1838
3/26	Wed	25.2	WB	3:21	4:06	Pasadena	WB I-210 Connector	Jackknife and diesel spill	936
4/1	Tue	25.4	WB	1:15	4:30	Pasadena	EB SR-134 Connector	Jackknifed big rig and MBGR damage	572
4/24	Thu	27.6	EB	12:56	11:46	Pasadena	Allen Ave	Big rig into center divider	27,730
5/29	Thu	35.2	WB	9:45	4:02	Duarte	Buena Vista Ave	Guardrail repair	4,360
8/3	Sun	25.0	WB	6:50	3:40	Pasadena	WB I-210 Connector	Emergency maintenance work	798
8/7	Thu	26.0	E/W	18:45	0:43	Pasadena	Los Robles Ave	Jumper	4,259
8/11	Mon	29.8	WB	14:32	4:58	LA County	Rosemead Blvd	Big Rig Accident	12,667
8/14	Thu	30.9	EB	4:10	2:45	Arcadia	Baldwin Ave	Fatality MC accident	1,273
11/3	Mon	29.8	EB	9:30	5:35	LA County	Michillinda Ave	Emergency slab repair	3,028
12/2	Tue	24.7	WB	22:28	3:00	Pasadena	EB SR-134 Connector	Overturned big rig	287
I-210 / I-605 to Los Angeles County Line									
3/21	Fri	37.7	WB	11:38	4:47	Irwindale	Irwindale Ave	Overturned big rig	28,734
6/11	Wed	48.2	EB	3:26	4:44	La Verne	Fruit St	Fatality, dump truck vs car	3,268
6/28	Sat	50.2	WB	1:33	3:02	Claremont	Towne Ave	Fatality accident	1,096
8/9	Sat	39.1	WB	3:08	4:22	Azusa	Vernon Ave	Fatality accident	5,326
8/18	Mon	38.2	EB	12:44	9:16	Irwindale	Irwindale Ave	Big rig/earth mover over the side	35,306
10/1	Wed	42.9	EB	15:52	7:43	Glendora	Sunflower Ave	Jackknifed big rig	21,054
SR-134 / SR-2 to I-210									
1/26	Sun	11.2	WB	0:00	2:35	Los Angeles	Figueroa St	Fatal wrong way driver	0
3/14	Fri	13.1	EB	9:00	6:10	Pasadena	WB I-210 Connector	Emergency guardrail repair	542
3/17	Mon	10.3	WB	11:14	7:02	Los Angeles	Arbor Dell Road	Cement mixer over the side	9,895
I-605 / I-10 to I-210									
8/20	Wed	22.2	SB	20:44	1:06	Irwindale	Lower Azusa Rd	Jumper	0
10/26	Sun	19.9	NB	11:23	3:14	Baldwin Park	WB I-10 Connector	Spilled load	280
12/4	Thu	20.5	SB	10:00	1:00	Baldwin Park	I-10 Connector	Emergency pothole repair	542
12/5	Fri	25.3	NB	8:30	3:40	Duarte	EB I-210 Connector	Guardrail repair	3,087
12/10	Wed	20.4	SB	10:46	3:16	Baldwin Park	I-10 Connector	Emergency slab repair	1,851
SR-57 / I-10 to I-210									
1/16	Thu	7.7	SB	23:00	3:30	San Dimas	I-10 Connector	Emergency slab repair	180
10/4	Sat	10	NB	5:26	7:24	San Dimas	Covina Blvd	Big rig fatality accident	14,634
11/12	Tue	8.1	SB	10:10	1:30	San Dimas	EB I-10 Connector	Guardrail repair	549
12/2	Tue	10	N/S	10:35	3:05	San Dimas	Covina Blvd	Big rig through center divider	3,982
12/23	Tue	8.1	SB	9:15	1:55	San Dimas	EB I-10 Connector	Emergency guardrail repair	608

Table 6-5 details the events for which the TMT was deployed in 2014. As was indicated in Section 5.5.6, the TMT is typically dispatched to assist motorists with emergency lane and freeway closures following an accident or emergency incident expected to last 2 hours or more. In 2014, this included responses to 48 events across the I-210 corridor and nearby freeways ranging in duration from 0.4 to 12.2 hours, with an average of 4.3 hours per event. The events that the team responded to included accidents, emergency repairs, suicide prevention situations, brush fires, and other situations.

Figure 6-26 and Figure 6-25, finally, compile the collision type and primary collision factor associated with the incidents that have occurred along I-210 between milepost 22.00 (Arroyo Boulevard) and milepost 47.3 (Foothill Boulevard) throughout 2012. This analysis is based on information contained in the Statewide Integrated Traffic Records System (SWITRS). Data from 2013 were not used, as not all accident records for 2013 had been entered into the system at the time of the evaluation.

The analysis period covers 423 incidents. Figure 6-26 indicates that 65% of recorded accidents that occurred along the section of I-210 of interest were rear-end collisions, i.e., collisions strongly related to the presence of congestion. If accidents associated with lane changing behavior are added to the statistics, such as sideswipe and broadside accidents, then nearly 80% of all recorded accidents could be linked to either congestion or traffic behavior. Figure 6-25 further indicates that a large majority of incidents were caused by driver-related factors, such as speeding (63%), unsafe lane change (12%), and

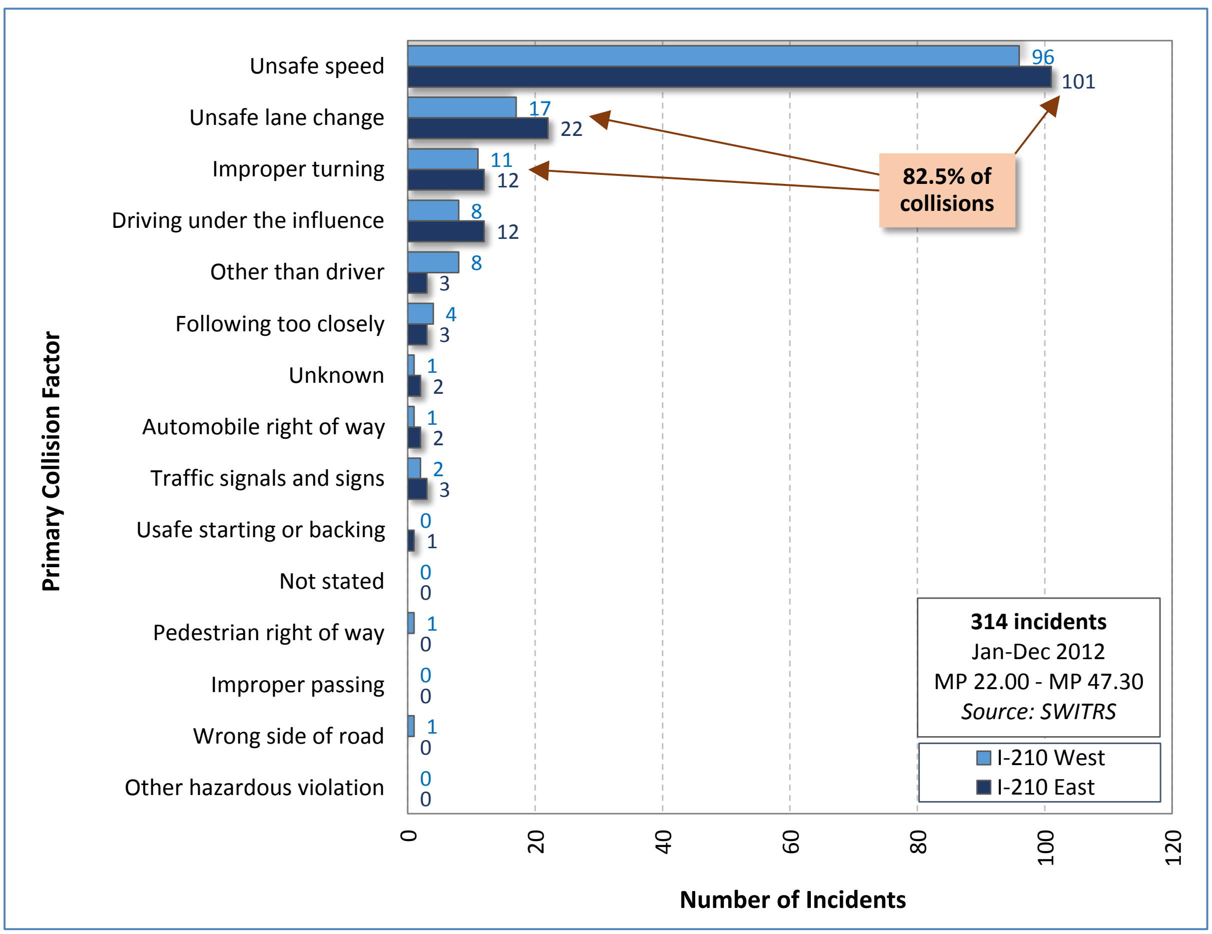


Figure 6-25 – Primary Cause of Injury and Fatal Collisions along I-210 in 2012

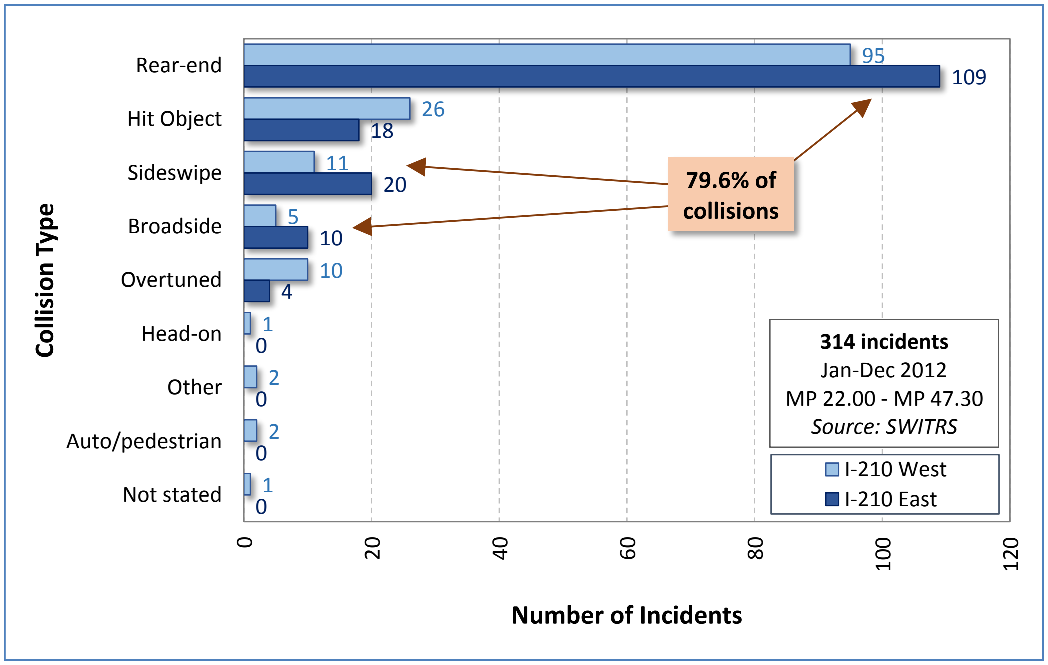


Figure 6-26 – Type of Injury and Fatal Collisions along I-210 in 2012

improper turn movements (7%). These statistics indicate that a strong potential exists along I-210 to reduce accident occurrences through improvements to congestion, lane-changing maneuvers, or other unsafe behavior.

6.3. ARTERIAL OPERATIONS

This section characterizes the following elements regarding arterial operations:

- Available capacity at key signalized intersections
- Traffic safety

6.3.1. AVAILABLE INTERSECTION CAPACITY

This section presents an assessment of the degree to which available traffic capacity at individual signalized intersections is used to accommodate recurrent traffic at the height of the AM and PM peak periods. This assessment was done by compiling the volume-to-capacity (v/c) ratio, or the equivalent Intersection Capacity Utilization (ICU) ratio, that have been estimated by various consulting firms over the past 8 years for various intersections as part of traffic signal retiming projects or traffic impact studies.

Figure 6-27 and Figure 6-28 present the results of the compilation for the AM peak and PM peak periods. The dates shown within each figure indicate when the various studies behind the illustrated information were conducted. Since the studies are spread in time, with the oldest from 2006, the analysis presented in this section should only be viewed as a rough assessment of available capacities. Changes made to the geometry of the intersections or the traffic signal operating parameters since the respective studies have been made may have noticeably improved their performance. Changes in traffic patterns may have further increased or decreased traffic demand at individual intersections and thus, resulted in either increase or deterioration in performance.

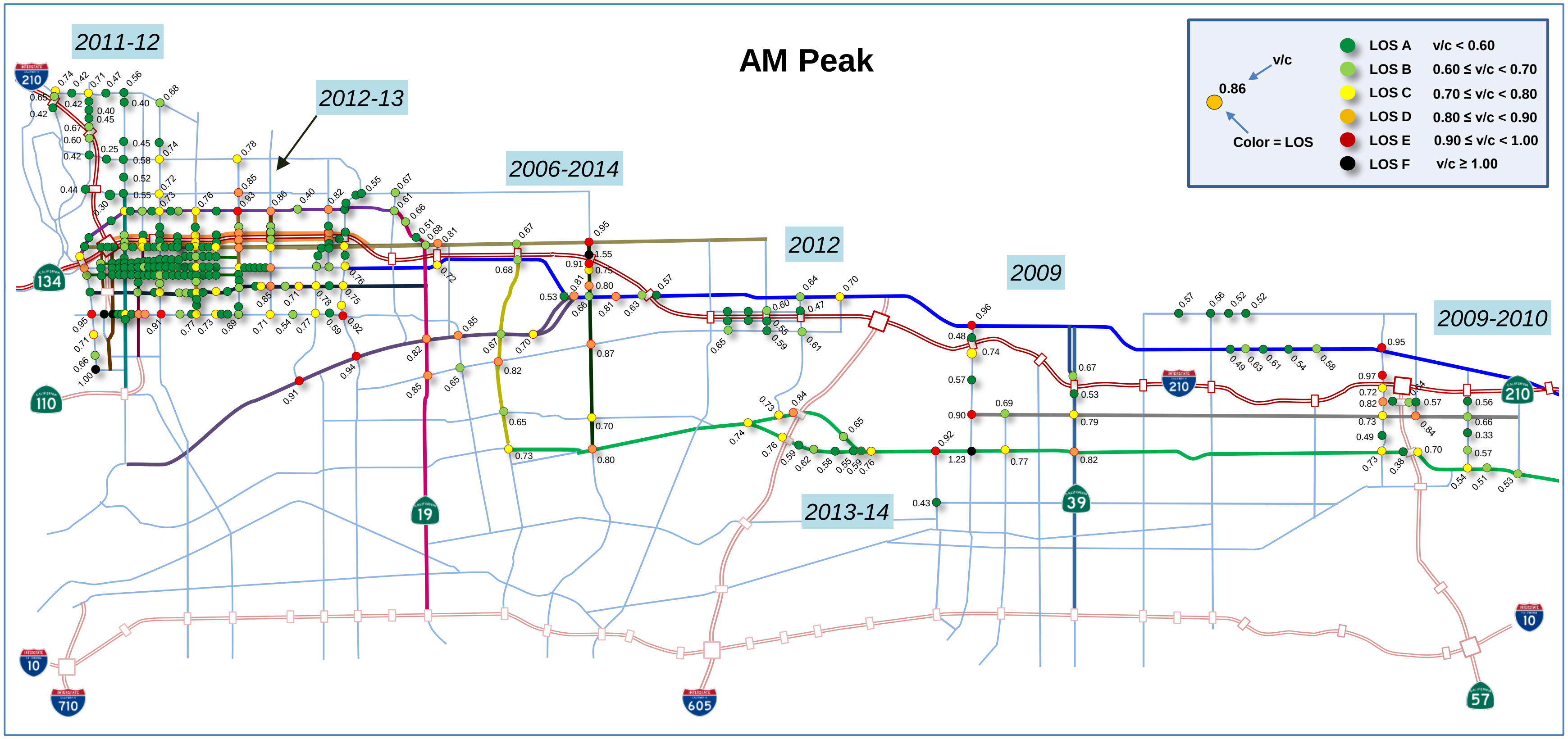


Figure 6-27 – Volume-to-Capacity Ratio at Signalized Intersections – AM Peak

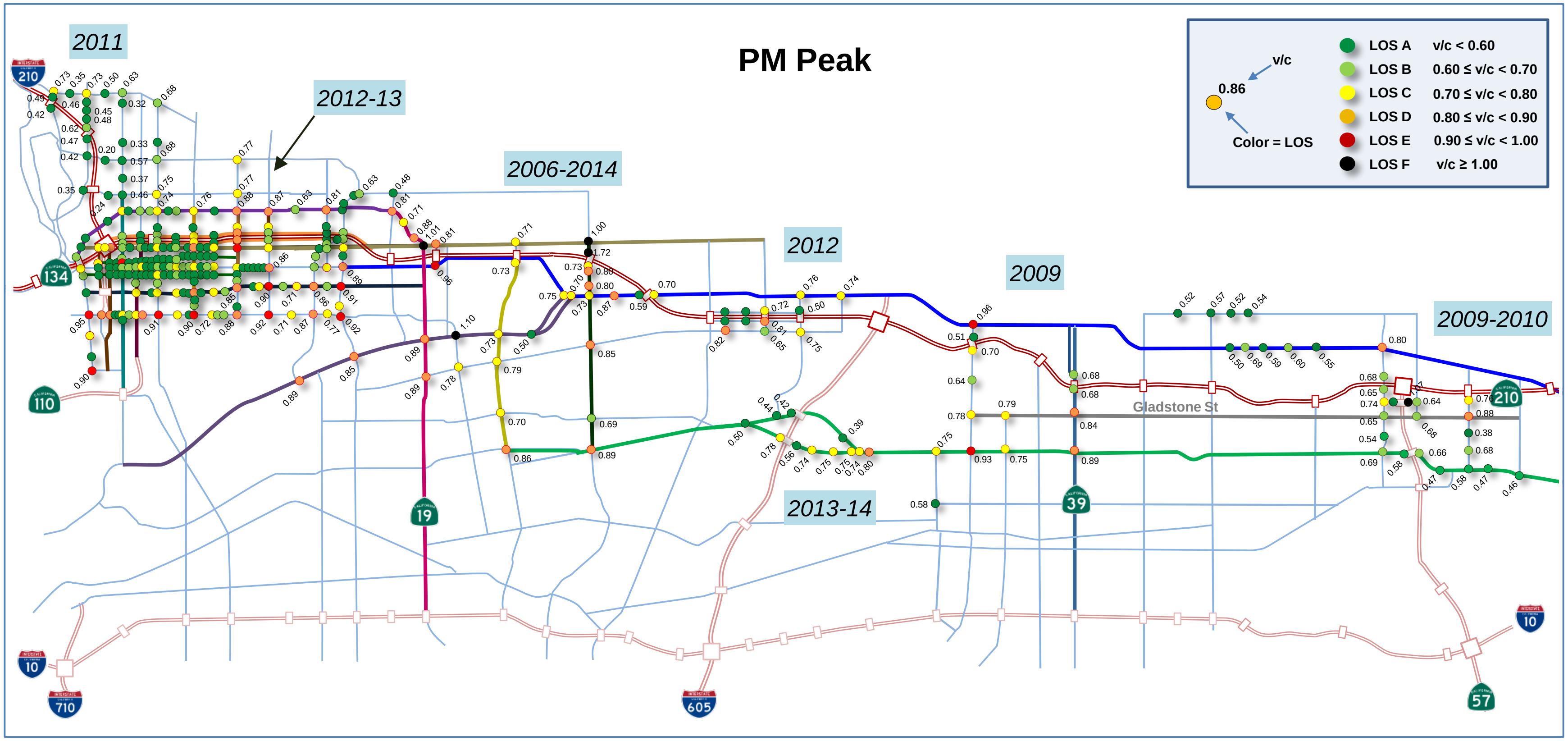


Figure 6-28 – Volume-to-Capacity Ratio at Signalized Intersections – PM Peak

At each intersection, the available capacity is the difference between the illustrated factor and 1.00. A factor of 0.85 thus means that 15% of the existing overall capacity of an intersection would theoretically be available to accommodate traffic surges, assuming that nothing would prevent shifting unused capacity from one approach to another when needed. It should also be noted that the statistics assess operational performance during the height of the peak hour, and thus represent the smallest available capacity for the period. Performance during other hours of the peak period may be slightly or noticeably better, depending on local traffic demand patterns. Across intersections, the interval when the highest traffic flows occur may also fluctuate. For instance, one intersection may experience its peak traffic between 4:30 and 5:30 PM, while another may experience it between 5:00 and 6:00 PM.

As can be expected, constrained capacities are found primarily at intersections along the busiest arterials. Intersections that may command particular attention when considering detours around incidents or events are listed in Table 6-6. Some are problematic only during the AM or PM peak period, while other have limited spare capacity during both periods. The intersections to pay particular attention to are those having less than 10% available capacity, shown in light gray in the table, and those with a utilization ratio above 100%, shown in black. The latter represent intersections for which demand reaches or exceeds capacity during portions of the peak hour and for which there would be no spare capacity to accommodate demand surges under the existing geometry and signal timings in operation.

Table 6-6 – Intersections with Potentially Limited Spare Capacity

Intersection	Jurisdiction	AM Peak Capacity Utilization	PM Peak Capacity Utilization	Date of evaluation
Orange Grove Boulevard & Columbia Avenue	Pasadena	1.00	0.91	2013
Orange Grove Boulevard & Hill Avenue	Pasadena	0.91	0.73	2013
Walnut Street & Allen Avenue	Pasadena	0.73	0.91	2013
California Boulevard & Orange Grove Boulevard	Pasadena	0.95	0.95	2013
California Boulevard & Saint John Avenue	Pasadena	1.21	0.90	2013
California Boulevard & Pasadena Avenue	Pasadena	1.21	0.90	2013
California Boulevard & Los Robles Avenue	Pasadena	0.91	0.91	2013
California Boulevard & Lake Avenue	Pasadena	0.77	0.90	2013
California Boulevard & Allen Avenue	Pasadena	0.71	0.92	2013
California Boulevard & San Gabriel Boulevard	Pasadena	0.92	0.92	2013
Del Mar Boulevard & Allen Avenue	Pasadena	0.85	0.90	2013
Del Mar Boulevard & San Gabriel Boulevard	Pasadena	0.75	0.91	2013
Colorado Boulevard & I-210 Eastbound Ramps	Caltrans	0.72	0.96	2006
Foothill Boulevard & Rosemead	Caltrans	0.68	1.02	2013
Foothill Boulevard & Santa Anita	Arcadia	0.95	1.00	2006
Santa Anita & I-210 East Ramps	Caltrans	0.93	0.88	2012
Santa Anita & I-210 West Ramps	Caltrans			2012
Huntington Drive & Santa Anita	Arcadia	0.91	0.86	2006
Huntington Drive & Sunset Boulevard	Arcadia	0.85	1.10	2006
Huntington Drive & Sierra Madre Boulevard	San Marino	0.91	0.89	2006
Huntington Drive & San Gabriel Boulevard	San Marino	0.94	0.85	2006
Irwindale Avenue & Foothill Boulevard	Irwindale	0.96	0.96	2009
Irwindale Avenue & Gladstone Avenue	LA County	0.90	0.78	2009
Irwindale Avenue & Arrow Highway	Irwindale	1.23	0.93	2009
Lone Hill Avenue & Route 66	Glendora	0.95	0.80	2009
Lone Hill Avenue & I-210 Westbound Ramps	Caltrans	0.97	0.68	2009
SR-57 Northbound Off Ramp & Auto Center Drive	Caltrans	0.64	1.07	2009

6.3.2. TRAFFIC SAFETY

Figure 6-29 maps the number of accidents that have been recorded near key signalized intersections within the western half of the I-210 corridor throughout 2012 and 2013. This assessment is based on data from the SWITRS database and the City of Pasadena. Approximately only 1,900 accidents of the reported 5,587 accidents are mapped. Accidents that have occurred at minor intersections or between two intersections are not shown. While accidents are shown to occur throughout the corridor, a few intersections present significantly higher frequencies of accidents. These are shown with a reddish circle in Figure 6-29 and identified in Table 6-7. Most of them are intersections carrying relatively high traffic.

Figure 6-30 and Figure 6-31 further compile the collision type and primary collision factor associated with all the incidents that have occurred in 2012 and 2013 within the cities of Pasadena, Arcadia, Duarte, and Monrovia, as well as the surrounding unincorporated county areas. This analysis is based on the same data that was used to develop the map in Figure 6-29 and includes all of the 5,587 incidents that have been recorded for the period. Key observations from each figures are as follows:

- Figure 6-30 indicates that 28% of accidents that occurred around signalized intersections were rear-end collisions, i.e., collisions strongly related to the presence of congestion. If accidents associated with lane changing behavior are added to the statistics, such as sideswipe and broadside accidents, nearly 78% of all recorded accidents could be linked to either congestion or traffic behavior.
- Figure 6-31 further indicates that a large majority of incidents were caused by vehicles being driven at unsafe speed (22% of accidents), or by drivers failing to respect right-of-way (16%), making improper turns (15%), or failing to respect traffic signs and signals (12%). These four factors account for nearly 64% of all recorded accidents.

The above statistics indicate that a strong potential exists along the I-210 to reduce accident occurrences through improvements to congestion, lane-changing maneuvers, or other unsafe behavior.

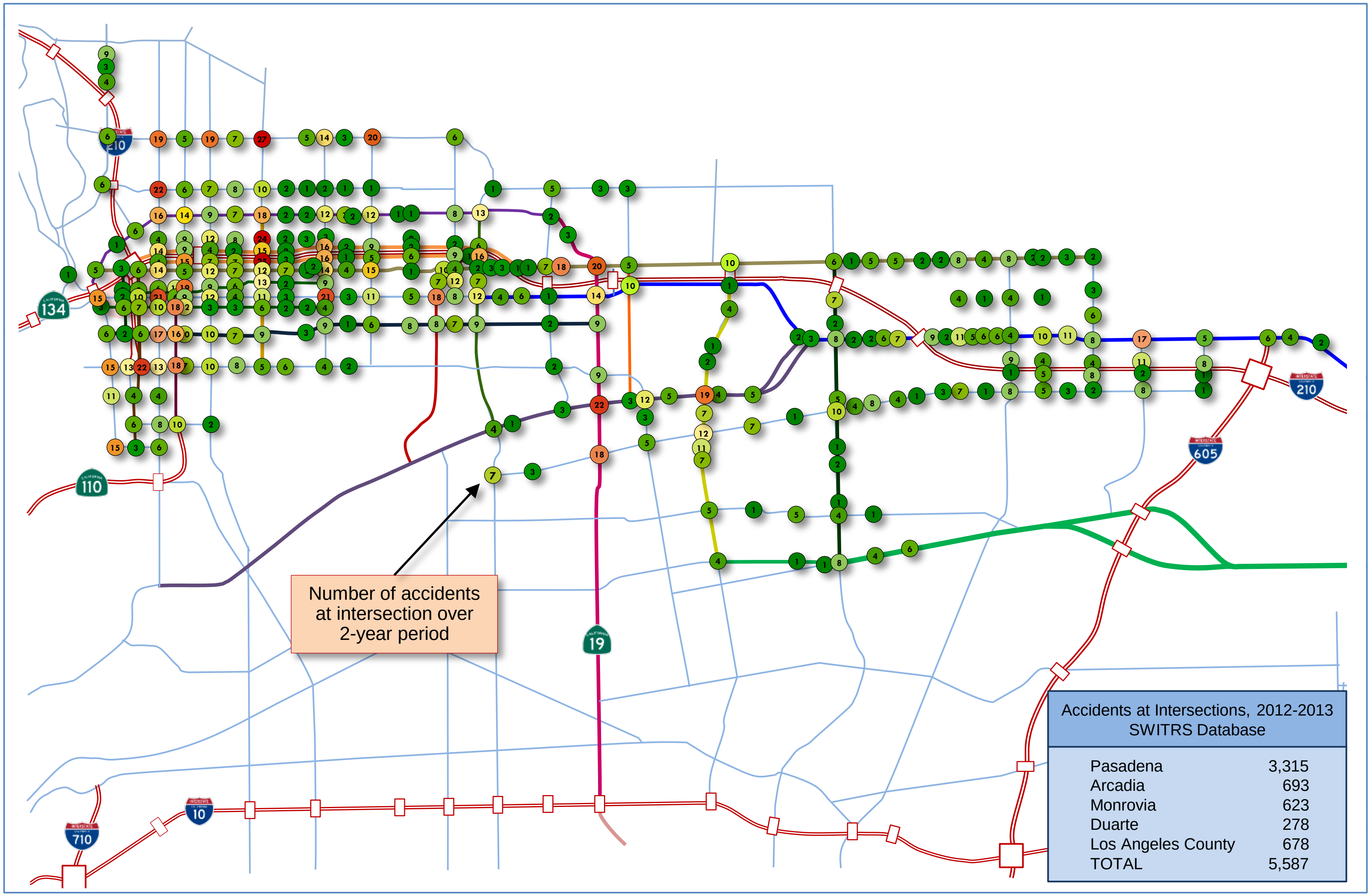


Figure 6-29 – Number of Accidents at Key Corridor Intersections in 2012-2013

Table 6-7 – Signalized Intersections with Highest Number of Accidents in 2012-2013

Jurisdiction	Intersection	Number of Accidents
Pasadena	Washington Boulevard / Lake Avenue	25
Pasadena	Corson Street / Lake Avenue	25
Pasadena	Villa Street / Lake Avenue	24
LA County	Huntington Drive / Rosemead Boulevard	22
Pasadena	Colorado Boulevard / Fair Oaks Ave	21
Pasadena	Colorado Boulevard / Hill Avenue	21
Pasadena	Mountain Street / Fair Oaks Avenue	21
Pasadena	Foothill Boulevard / Rosemead Boulevard	20
Pasadena	Washington Boulevard / Allen Avenue	20
Pasadena	Union Street / Marengo Avenue	19
Pasadena	Foothill Boulevard / Sierra Madre Ville Avenue	19
Arcadia	Huntington Drive / Baldwin Ave	19
Pasadena	Washington Boulevard / Fair Oaks Avenue	19
Pasadena	Washington Boulevard / Los Robles Avenue	19
Pasadena	Green Street / Arroyo Parkway	18
Pasadena	Colorado Boulevard / Sierra Madre Boulevard	18
Pasadena	Orange Grove Boulevard / Lake Ave	18
Pasadena	Del Mar Boulevard / Fair Oaks Avenue	17
Duarte	Huntington Drive / Buena Vista Ave	17
Pasadena	Del Mar Boulevard / Arroyo Parkway	16
Pasadena	Maple Street / Hill Ave	16
Pasadena	Corson Street / Hill Ave	16
Pasadena	Orange Grove Boulevard / Fair Oaks Avenue	16

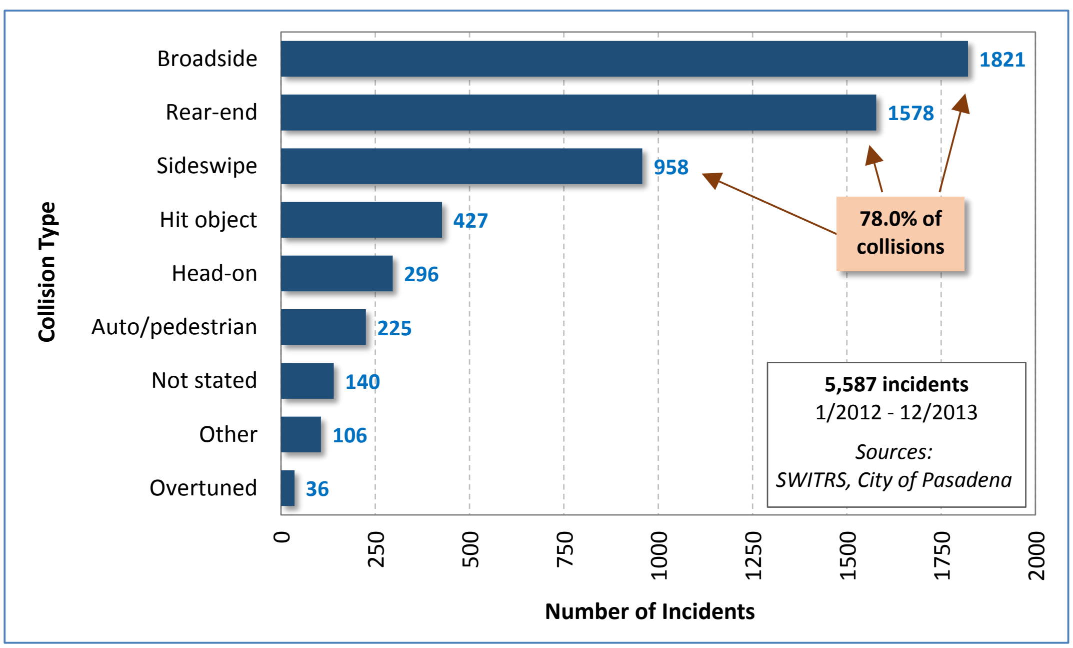


Figure 6-30 –Collision Types along Corridor Arterials in 2012-2013

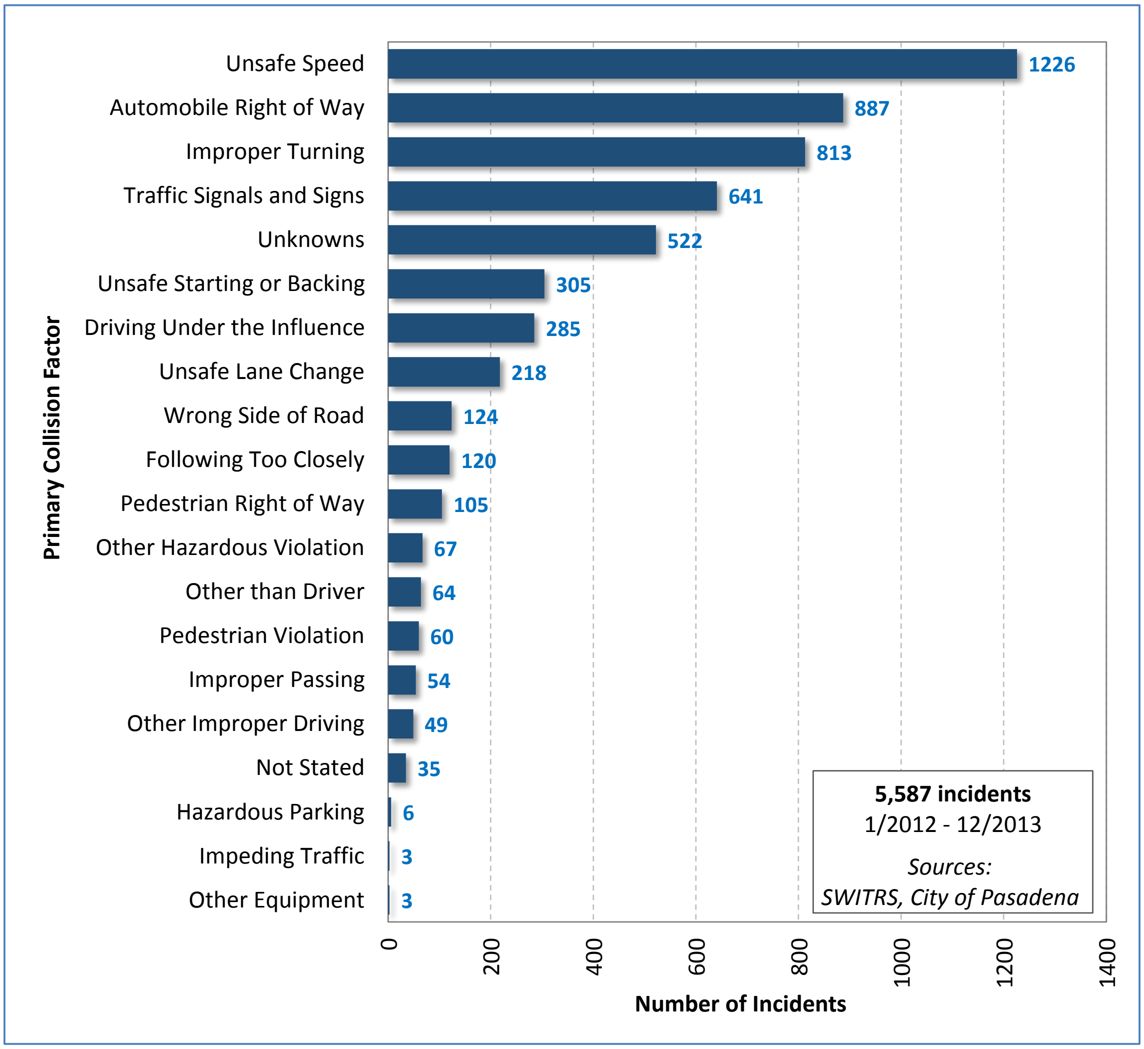


Figure 6-31 – Primary Causes of Collisions along Corridor Arterials in 2012-2013

6.4. TRANSIT OPERATIONS

This section presents summary statistics about the on-time performance of transit services within the I-210 corridor. Other commonly cited statistics in transit performance reports, such as total ridership, miles traveled, or fare revenues are not presented, as these statistics would have little incidence on the needs assessment of an ICM system. While ridership is an important measure of overall demand, a metric of greater importance is vehicle occupancy, as this metrics allows determining how much additional demand could be accommodated. However, vehicle occupancy is often not readily available. Where it is, only an average occupancy may be available while an occupancy for specific route segments is needed.

For fixed transit routes, on-time performance is generally defined as a vehicle departing from a given time point within 0 to 5 minutes from the time identified on the published route schedules. Below are the most recent on-time performance evaluations that could be retrieved:

- **Metro Bus –** The latest customer survey, conducted in May 2012, had 76% of 20,730 bus riders indicating that the bus they had taken arrived within 5 minutes of its scheduled time.

- **Metro Rail –** Results from the latest customer survey, conducted in May 2012 had 85% of 1143 respondents indicating that the train they took arrived within 5 minutes of its scheduled time.
- **Foothill Transit –** At its August 2013 performance evaluation, Foothill Transit evaluated that its fixed-route buses were on-time 73.0% of the time. The commuter express service was further assessed to have an overall on-time performance of 77%. Road construction along major roads within the service area is noted to have caused some service delay and to have affected on-time performance. An increase in arterial traffic associated with the beginning of the school year is also cited as having an impact on on-time performance.
- **Pasadena Transit –** At the mid-2014 fiscal year evaluation, buses operated by the City of Pasadena were reported to have an 80.49% on-time performance. This was consistent with the standard industry standard of achieving 80% on-time performance. For fiscal year 2015, a higher 85% on-time performance is being sought by the agency.
- **Metrolink Commuter Rail –** For the second half of 2010, Metrolink reported monthly average on-time performance varying between 93% and 96%, and between 94% and 97%, when removing from consideration external factors such as trespasser incidents and extreme weather events.

6.5. PARKING OPERATIONS

Available information on park-and-ride facilities suggests a very high-level of utilization during the day. As shown in Figure 6-32, recent occupancy surveys indicate that many facilities exceed 90% occupancy on average during the day. This is particularly true for parking facilities along the Metro Gold Line where parking is free of charge, as well as several park-and-ride lots along I-210. Such a high level of occupancy indicates that limited excess parking capacity currently exists throughout the corridor.

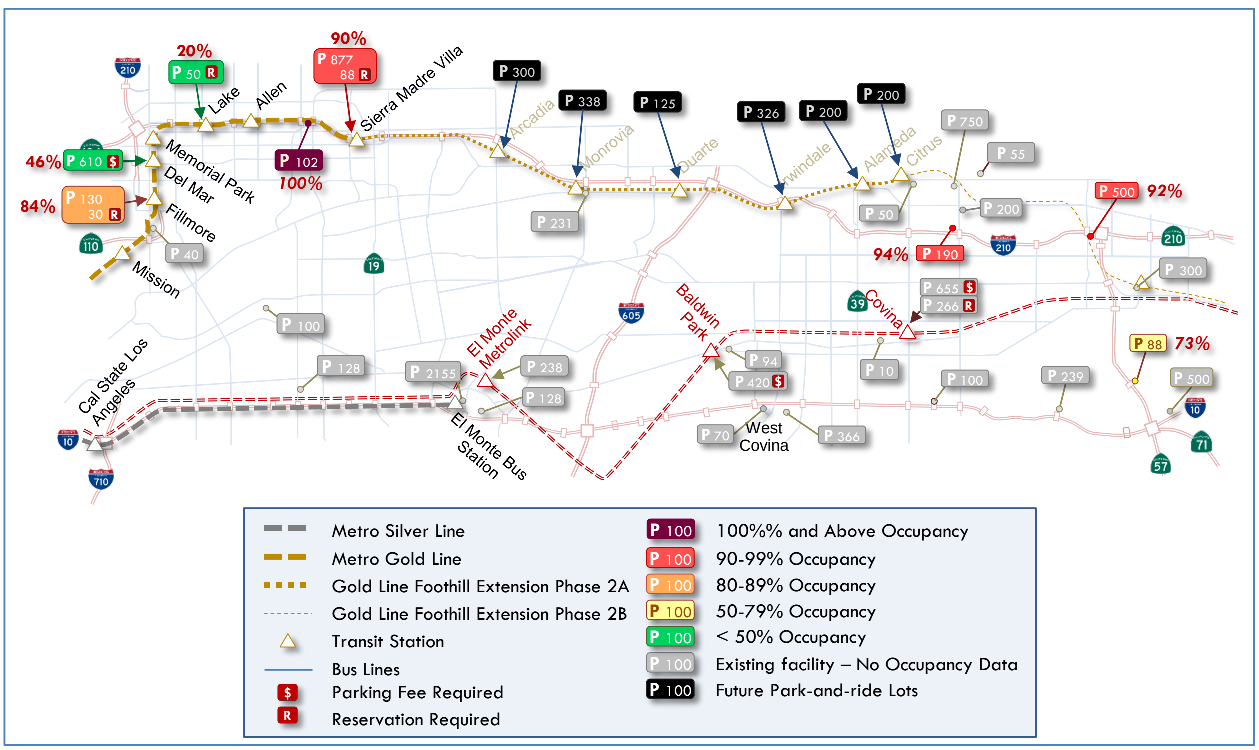


Figure 6-32 – Park-and-Ride Occupancy Rates

Occupancy levels of general parking facilities depend on their location and time of day. Anecdotal evidence suggests that many of the privately operated facilities around downtown Pasadena are fully utilized during the day by employees of adjacent businesses. Facilities catering primarily to retail business customers, such as city-owned facilities, may have some space capacity.

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7. JUSTIFICATION FOR CHANGES

This section presents a justification for the proposed ICM system for the I-210 corridor. Specific elements presented in this section include:

- Operational, informational, and institutional gaps in current corridor operations
- Environmental and financial influencing factors
- Desired operational changes
- Priorities among desired changes

7.1. OPERATIONAL, INFORMATIONAL, AND INSTITUTIONAL GAPS

The following operational, informational, and institutional gaps currently affect the ability to manage and operate the I-210 corridor to its full potential:

- **Transportation system monitoring capability**
    - Limited ability to monitor traffic conditions in real time on corridor arterials. While most signalized intersections are equipped with traffic detectors, only a small fraction of signal controllers are currently set up to forward the data they collect to the associated TMC in real time. This results in a limited ability to track changes in traffic conditions as they occur for large portions of the corridor.
    - Predominant reliance on estimated travel patterns. Corridor travel patterns are typically derived from regional travel demand models or techniques developing origin-destination flow matrices based on observed traffic counts. There are very few direct observations of routing decisions made by travelers. This limits the ability of traffic managers to assess the effectiveness of implemented strategies aiming to affect routing decisions.
    - Travel forecasts used by traffic managers remain largely based on historical data analyses. No agency within the corridor uses algorithms attempting to forecast in real-time the travel times that may be experienced by travelers. Travel time estimates are typically compiled by adding up the travel times on individual sections corresponding to the speeds currently observed everywhere.
    - While emerging crowd-sourcing applications increasingly attempt to forecast travel times that travelers may actually experience based on extrapolations of historical and current traffic data, they do not usually have access to operational data (for instance, signal timing data). This can significantly degrade the accuracy of the forecasts and undermine acceptance of the application by travelers.
    - Limited real-time information about transit capacity utilization. Due to the difficulty of doing so, passenger boarding and alighting are not compiled on a day-to-day basis for light-rail trains operated by Metro. While onboard passenger counters automatically compile this information for buses operated by Metro and Foothill Transit, the collected data is typically only retrieved when a vehicle returns to its garage. This lag prevents tracking transit capacity utilization in real time and assessing how transit services may be affected by an incident.

  - Limited real-time information about parking availability, both at publicly and privately operated facilities. Very few facilities within the corridor have systems counting the number of vehicles present. This results in an inability to assess whether a lack of parking may be an impediment to the promotion of transit alternatives or transit use in general.

- **Operational performance assessment**
  - While PeMS can be used to assess the effectiveness of freeway operations in near-real time, no similar tool exists for assessing arterial performance. While third-party information tools such as Google Maps are increasingly being used to visualize traffic speeds on main arterials and locate congestion hotspots, these tools do not provide many of the performance metrics of interest to roadway managers, such as incurred delays, volume-to-capacity ratios, etc.
  - Different agencies use different metrics for assessing the operational performance of roadway elements. This is often the result of different traffic management policies. While one agency may focus on travel times and delays, another may focus instead on reliability. A need thus exists to define a set of performance metrics adequately capturing both local and corridor-wide control objectives.

- **Traffic signal control capability**
  - While the vast majority of traffic signals within the corridor are connected to a TMC, some key signals remain unconnected. This is the case for most of Caltrans' signals at the end of freeway ramps, as well as some signals in Monrovia and Duarte. The inability to communicate with these signals from a central location prevents the implementation of unscheduled changes in traffic operations, as changes must be entered directly into the signal controller by personnel.

- **Information sharing capability**
  - No direct communication links currently exist between the various TMCs operating within the corridor.
  - While both the IEN and RIITS communication networks were developed to facilitate data exchanges among agencies, both still provide constrained communication capabilities. While the IEN was developed to support the exchange of signal timing data, it does not currently support the exchange of traffic flow data collected from roadway detectors. On the other hand, while RIITS can circulate both signal and traffic flow data, very few agencies within the I-210 corridor have developed interfaces with this system.
  - Where data sharing is possible, different data-gathering and recording practices often make sharing cumbersome or difficult. For instance, while Arcadia's TransSuite system records the duration of each traffic signal phase on a cycle-by-cycle basis, Pasadena's i2 system records when a particular signal indication changes from green to yellow, yellow to red, or red to green. Comparing data collected by the two systems thus requires some processing to convert the data to a common reference framework.

- **Collaboration among agencies managing transportation systems within the corridor**
  - Limited collaboration exists between Caltrans and local jurisdictions. Freeway and arterials are managed as independent systems, each with their own objectives. This

occasionally results in Caltrans making decisions regarding freeway operations that may have detrimental effects on local arterials, or in local agencies making traffic management decisions that may negatively affect freeway operations.

- Local agencies typically manage their road network independently of surrounding networks, sometimes with different objectives. While some regional signal synchronization projects have promoted inter-agency coordination along specific arterial corridors, arterials signals are for the most part independently set up by the agency having jurisdiction over them based on criteria, communication capabilities, and priorities set up by the agency. This has often resulted in coordination breaks at jurisdictional boundaries.
- Limited coordination between roadway and transit operators. Traffic signals along the arterials are primarily set up based on general traffic flow needs. Apart from a few locations where the signals have been equipped with a transit signal priority system, transit-specific mobility needs are typically not considered by roadway agencies when developing arterial mobility plans. While transit agencies often develop schedules reflecting congestion, this is often only an attempt to reflect actual expected service performance.
- Transit agencies operating within the corridor typically set their service schedules independently of each other. While some service coordination may exist at some intermodal stations, such coordination is often the result of customer requests and not necessarily the result of a continuous agency collaborative process.

- **Incident response management**
  - While significant efforts have been made to develop efficient incident management responses, traffic management decisions made by law enforcement officers remain generally based on local operational and safety situational assessments. Greater coordination between law enforcement officers, first responders, traffic managers, and transit operators is needed to ensure that efficient detours around incidents are implemented, particularly for incidents occurring during peak travel periods.

- **Traveler information systems**
  - Existing traveler information systems typically estimate the time needed for a given trip based on current conditions or historical data. This results in travel time estimates not necessarily corresponding to the experienced travel time. By the time a traveler reaches a certain location, a congestion hotspot that previously existed may have dissipated. No traveler application yet attempts to forecast the travel times that travelers may actually experience based on the conditions they are likely to encounter along each segment of their trip when they actually reach each segment.
  - While various existing routing applications can already provide detour recommendations around incidents, these applications do not necessarily have an accurate view of operating conditions in the network. In addition, they do not track how many travelers adjust their travel plans based on the information provided. As a result, these applications can cause too many vehicles to reroute through the same arterials and creating new congestion problems.

  - Trip planning tools remain mainly informational in nature. In most cases, tool users are left with the task of comparing trips by themselves. The potential for suggesting trip alternatives or incentivizing travel behavioral changes is not fully used.

The various gaps identified prevent many transportation elements from being used to their full potential, thus resulting in unused or inefficiently used transportation capacity. The problems are associated with both the supply side and demand side of the transportation system:

- On the supply side, better system awareness, operational tools, and coordination among various transportation system operators can increase the efficiency with which existing systems are being managed and operated.
- On the demand side, enhancing information dissemination may enable travelers to make informed decisions that may lead to a more efficient distribution of trips across time and modes. While travelers often make decisions based on their experience, they do not always have comprehensive or accurate knowledge of the alternative travel options that are available to them. As a result, travelers often reject alternative travel options based on inaccurately perceived difficulties. In this case, better information would help alleviate these problems.

7.2. ENVIRONMENTAL AND FINANCIAL INFLUENCING FACTORS

Several additional environmental and financial factors reinforce the need to make a more efficient use of existing transportation systems:

- **Limited available right-of-way**
  - Limited land availability, particularly in core urban areas, makes it difficult to consider road-widening projects to alleviate operational problems. Along many corridor arterials, widening roads would require land purchases, building demolition, and a lot of funding. Since such options are likely to be highly unpopular, this increases the need for solutions that can be implemented within the existing right-of-ways.
- **Limited funds for large-scale capital infrastructure investments**
  - Many agencies are now operating with limited budgets. This makes it difficult to justify expensive infrastructure projects and leads to a need to find solutions that can be implemented within the existing infrastructure or with minimal changes.
- **Limited funds for operations and maintenance support**
  - Funding sources for corridor improvements often exclude operations and maintenance as eligible expenses. This leaves each agency responsible for finding the funds required for the operations and maintenance of newly deployed equipment. Projects proposing significant deployment of new equipment will often have to compete with existing systems for fund allocation.

7.3. DESIRED CHANGES

This section identifies key desired changes that would help address the gaps identified in Section 7.1 and improve overall corridor operations:

- **Enhance communication capabilities with field devices**
  - Provide fast, reliable communication lines with field devices
  - Enable real-time or near-real-time communication with relevant field devices

- **Expand traffic and travel monitoring capabilities**
  - Increase the number of arterial detectors providing traffic volumes and turning counts
  - Increase the ability to monitor travel times between specific locations
  - Enable traffic and travel monitoring systems to provide data in real time
  - Increase the ability to track vehicle routing patterns
  - Increase the ability to visually assess conditions on managed roadways and systems
  - Produce performance-based metrics supporting various operational and reporting needs

- **Improve the ability to respond quickly to changes in travel demand, congestion, or operating conditions**
  - Provide tools allowing system operators to assess quickly the potential operational impacts of the control and management strategies being considered
  - Enable all relevant traffic management devices to be centrally controlled from the associated TMC
  - Improve communication between the various transportation management centers operating in the corridor
  - Improve communication between transportation management centers and transit operation centers managing services within the corridor

- **Provide system managers with integrated, multi-system decision-support tools**
  - Develop integrated processes for gathering, validating, analyzing and distributing data
  - Implement standardized system interfaces and data communication protocols
  - Develop integrated tools for planning, design, and evaluation
  - Develop optimization tools considering the needs and capabilities of all transportation elements and system users within a corridor
  - Develop interagency agreements promoting integrated operations and management

- **Improve coordination among transportation systems**
  - Increase data sharing capabilities among agencies operating within a corridor
  - Enhance coordination between freeway and arterial traffic management operations
  - Enhance coordination between roadway and transit operators
  - Enhance coordination operations among transit agencies
  - Enhance coordination among law enforcement agencies, first responders, freeway operators, and arterial operators during incidents

- **Improve the dissemination of real-time travel information to motorists, transit riders, and other travelers**
  - Provide comprehensive incident/event information to corridor travelers
  - Improve information dissemination to en-route travelers, particularly hands-free delivery capabilities to motorists
  - Provide reliable travel time forecasts based on current and projected transportation system conditions
  - Provide real-time parking availability at park-and-ride facilities to travelers

- **Improve the ability to proactively influence travel demand and promote route, mode and/or time-of-day shifts**
  - Improve the ability to communicate en-route information to travelers
  - Provide effective dynamic route guidance around problem areas in response to incidents, planned events, or unusual situations
  - Improve the ability for travelers to obtain and compare information about trips based on various alternative transportation modes
  - Improve the ability for traffic managers to influence travel mode and itinerary choices through targeted traffic control actions and information dissemination

The end goal is to develop a corridor-based transportation management system providing:

- Enhanced real-time control capabilities
- Reliable information about current and projected travel conditions within the corridor
- Performance-based metrics supporting operations and reporting needs
- Coordinated operations across various transportation systems and modes
- Improved corridor-wide travel performance within individual and across multiple modes
- Greater partnership opportunities between regional transportation agencies, local agencies, and private sector entities.

7.4. PRIORITIES AMONG DESIRED CHANGES

This section presents a prioritization of the desired changes to improve the operations and management of the I-210 corridor that have been identified in Section 7.3. The need for this prioritization is based on the recognition that not all identified changes carry the same operational impact factors. Some changes may also easier to implement than others, particularly when considering the current constrained fiscal environment. For instance, changes requiring significant instrumentation deployments or infrastructure modifications are less likely to obtain approval from stakeholders if adequate funding is not already secured. Operational changes relying on innovative applications of technologies may also require more development time than changes replying on small procedural changes or the use of infrastructure that is largely already in place. An effective implementation strategy would be one that focuses first on the implementation of changes yielding high benefits for a low deployment cost. The success of these early applications could then be used to support the development and implementation of more complex or resource-intensive changes.

In the above context, Table 7-1 identifies the priority level of the various categories of desired changes listed in Section 7.2. Each desired change is assigned a value between 1 (highest priority) and 3 (lowest

Table 7-1 – Priority among Desired Changes

Desired Change	Priority
Enhance communication with field devices	1
Expand traffic and travel monitoring capabilities	1
Improve the ability to respond in real time to observed changes in travel demand, congestion or operating conditions	1
Improve coordination of operations among transportation systems elements	1
Provide system managers with integrated, multi-system decision-support tools	1
Improve the dissemination of real-time travel information to motorists, transit riders, and other travelers	2
Improve the ability to influence travel demand within a corridor to promote route, mode, and/or time-of-day shifts	3

priority). It is anticipated that changes with a high priority will be strong candidates for short-term implementation, while changes with low priority may be considered over a long-term horizon or fully removed from consideration.

The rationale for the various assigned priorities is based on the following factors:

- The ability to monitor in real time changes in operational conditions is of paramount importance. Without information characterizing travel conditions within the corridor, the proposed ICM system could not conduct operational evaluations and assess whether changes in management strategies are desired. This has led to the attribution of a Priority 1 level to the first three items in the table.
- Coordination of operations is a foundational element of the proposed ICM system. The system aims to bring together various systems that are currently typically operated independently from each other. For this reason, the fourth item was also assigned a Priority 1 level.
- The development of integrated, multi-modal operational tools is important to facilitate data processing and development of objective processes to assess operational benefits across modes and jurisdictions. This includes the development of the proposed Decisions Support System and all associated data processes. For this reason, changes under this category were assigned a Priority 1 level.
- Some operational improvements can be achieved without supporting information dissemination. For instance, simply changing traffic signal plans or ramp metering rate may be sufficient in various cases to implement efficient detours around incidents. In addition, improvements in the dissemination of information cannot be achieved before adequate monitoring and evaluation systems are in place. For these reasons, a Priority 2 level was assigned to changes focusing on improving information dissemination.
- The implementation of strategies aiming to change travel behavior is finally seen as a more long-term goal. These changes also cannot be effectively realized until adequate travel monitoring and information dissemination are in place. Because of these considerations, a Priority 3 level was assigned to the last category of desired changes.

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8. PROPOSED SYSTEM CONCEPT

This section provides a high-level conceptual and operational description of the ICM approach proposed for the I-210 corridor. While the elements presented here are commonly associated with ICM systems, not all of them may be implemented in the I-210 corridor project. Elements discussed here include:

- Vision for integrated corridor management
- Goals and objectives of proposed ICM system
- Key underlying concepts influencing system development
- Potential operational approaches and strategies
- Strategies deliberately excluded from consideration
- Potential ICM system operational framework
- Potential system outputs

8.1. INTEGRATED CORRIDOR MANAGEMENT VISION

The proposed I-210 ICM system is based on the recognition that there is an increasingly limited ability to improve network operations through large-scale infrastructure projects, thus creating a greater reliance on operational improvements and demand-related solutions to address current and future transportation needs. While it is recognized that improvements to the operation of individual systems and the introduction of new applications can each be beneficial, greater gains can likely be achieved through integration of the various transportation management systems currently used in a corridor and greater operational collaboration among corridor stakeholders.

8.2. GOALS AND OBJECTIVES OF ICM SYSTEM

As indicated in Section 2.3, the primary goal of the proposed system is to improve the movements of vehicles along the I-210 corridor during incidents and events. The end goal is to improve overall corridor performance by increasing the efficiency with which existing systems and infrastructures are being used to manage the incident or event through the implementation of cross-jurisdictional traffic and demand management strategies considering all relevant modes of transportation. This translates into the following specific incident and event management goals:

1. Improve operational situational awareness
2. Promote collaboration among corridor stakeholders
3. Improve incident response
4. Improve travel reliability
5. Improve overall corridor mobility
6. Empower travelers to make informed travel decisions
7. Facilitate multi-modal movements across the region
8. Promote transportation sustainability by reducing impacts on the environment
9. Improve corridor safety

For each of these goals, Table 8-1 further identifies the main operational objectives. Many of the objectives are similar to those of traditional transportation improvement projects. Many, however, also support a vision that operational and managerial gains can be achieved by implementing more comprehensive travel and system status monitoring systems, improved operational forecasting, improved information dissemination to travelers, enhanced data sharing capabilities, novel demand management approaches, and improved collaboration among transportation system operators.

Table 8-1 – ICM System Goals and Objectives

Goals	Objectives
1. Improve situational awareness – Improve the availability and quality of data characterizing travel conditions within the corridor.	• Establish minimum requirements for data collection to support system management • Increase data collection opportunities from arterials and local roads • Improve the collection of real-time operational data from non-traditional sources, such as probe vehicles • Develop a comprehensive corridor informational database covering all relevant travel modes within the corridor • Improve the quality, accuracy and validation process of collected data • Increase the ability to estimate travel demand patterns in a multi-modal environment • Improve the ability to forecast near-future travel conditions based on known incidents, road conditions, weather, and local events • Develop performance metrics considering all available travel modes
2. Promote collaboration among corridor stakeholders – Facilitate the exchange of information and consensus building among agencies operating roadways, transit services, and traveler information services	• Strengthen existing communication channels among corridor's institutional stakeholders • Explore new opportunities, where appropriate, for new communication links between corridor stakeholders • Improve cooperation and collaboration among corridor stakeholders. • Develop regional/joint operations concepts • Identify new and established methods of collaboration leading to successes • Extend corridor performance metrics to the network level • Investigate new types of agreements in addition to memorandum of understanding (MOUs), cooperative agreements, etc.
3. Improve response to incidents and unexpected events – Reduce the time needed to return operating conditions to normal following incidents or unexpected situations	• Reduce the time needed to identify the existence of an incident or unexpected situation • Reduce the time needed to respond to incidents • Enhance the coordination of activities between first responders, traffic management agencies, and transit agencies to minimize impacts on system operations • Reduce the time needed to implement control actions to address congestion resulting from an incident • Reduce the time needed to disseminate recommended travel options around an incident
4. Improve travel reliability – Develop a multi-modal transportation system that adequately meets customer expectations for travel time predictability.	• Improve travel time predictability along the corridor • Reduce the impacts of incidents and events on network operations • Improve incident notification for first responders and network operators • Improve incident notification to travelers and fleet operators • Provide travelers and commercial vehicle operators affected by an incident an enhanced ability to seek alternate routes or mode of transportation

Table 8-1 - ICM System Goals and Objectives

Goals	Objectives
5. Improve overall corridor mobility – Facilitate the movement of vehicles, people and goods across the corridor.	• Reduce delays incurred by travelers • Reduce the impacts of incidents and events on network operations • Efficiently use spare capacity along corridor roadways to plan necessary detours around incidents or events • Promote strategies to induce desirable travel demand patterns • Coordinate the management of freeway and arterial bottlenecks • Promote increases in vehicle occupancy • Promote increases in transit ridership
6. Empower system users to make informed travel decisions – Deliver timely, accurate, and reliable multi-modal information to transportation system users, allowing them to make informed choices regarding departure time, mode (for travelers), and route selection.	• Improve the dissemination of real-time, multi-modal travel information • Enhance the use of infrastructure-based informational devices (freeway CMS, arterial trailblazer signs, kiosk, etc.) to provide en-route information to travelers • Enable individuals to receive travel information on connected mobile devices • Make archived historical data available to information service providers • Support the dissemination of travel information by third-party providers
7. Facilitate multi-modal movements across the region	• Promote the integration of commuter rail and commute bus services with corridor operations • Facilitate transfers across modes during incidents and events • Provide relevant regional travel information to travelers • Direct travelers to park-and-ride facilities with available spaces
8. Promote transportation sustainability – Reduce the impacts of transportation activities on the environment, and improve the impacts on the economy, and quality of life.	• Reduce fuel consumption • Reduce vehicle emissions • Identify financially sustainable solutions that account for long-term system operations and maintenance • Encourage the use of transit, walking, and bicycling where appropriate • Support locally preferred alternatives compatible with corridor objectives • Develop and implement performance metrics reflecting environmental goals • Educate the public about transportation sustainability through media outlets
9. Improve corridor safety – Reduce deaths, injuries, property losses, and economic losses by reducing the occurrence of preventable accidents and the severity of occurring accidents.	• Reduce collision rates • Reduce the severity of collisions • Reduce the number of fatalities • Reduce the impacts of primary and secondary incidents on network operations through improved incident management

8.3. INFLUENCING CONCEPTS

This section identifies various elements influencing the design of the proposed ICM system. These elements include legislation and frameworks influencing investment decisions and how transportation systems should be operated, emerging capabilities introduced by recent technological innovations, and approaches promoting the efficient operations of multi-modal transportation systems. Key influencing elements described in more detail below include:

1. Regional transportation plans
2. MAP-21 performance management approach
3. Caltrans' strategic growth approach
4. Caltrans' Smart Mobility Framework
5. Leveraging continuous traveler connectivity enabled by connected mobile devices
6. Leveraging emerging probe vehicle data collection capabilities
7. Use of quick-response evaluation tools
8. Promotion of proactive traffic management approaches
9. Gradual path to the integrated management of multi-modal transportation systems

8.3.1. REGIONAL TRANSPORTATION PLANS

The improvement strategies an ICM system proposes should follow the priorities established by regional and local planning organizations in their regional transportation plans. These plans identify where investments should go to improve existing systems and develop new infrastructures so the resulting transportation system meets the region's goals, such as improved mobility, system sustainability, reduced environmental impacts, etc.

Figure 8-1 – Metro's 2009 Long Range Plan

Key planning documents that were considered for the development of the I-210 Pilot include:

- SCAG's 2012-2035 Regional Transportation Plan
- Metro's 2009-2040 Long Range and 2014-2024 Short Range Transportation Plans
- City of Pasadena's 2009 Intelligent Transport Systems Master Plan Framework

8.3.2. MAP-21 PERFORMANCE MANAGEMENT APPROACH

The Moving Ahead for Progress in the 21st Century Act, commonly known as MAP-21, was signed into law by President Obama on July 6, 2012. This legislative act establishes an outcome-driven, performance-based approach holding State Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) accountable for improving the condition and performance of their transportation assets.

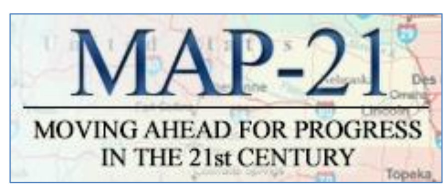

Figure 8-2 – MAP-21

Under MAP-21, the USDOT was first tasked with establishing performance measures supporting the following goals for the national transportation network:

- Reduce traffic fatalities and serious injuries on all public roads
- Maintain the highway infrastructure assets in a state of good repair
- Achieve significant reduction in congestion on the National Highway System
- Improve the efficiency of the surface transportation system
- Improve freight movement and economic vitality
- Enhance the performance of the transportation system while protecting and enhancing the natural environment
- Reduce project delivery delays

Following the identification of suitable performance metrics, the DOTs and MPOs were required to set performance targets supporting the identified goals and to periodically report to the USDOT on progress in achieving the established targets. The general expectation is that the utilization of performance targets will provide these agencies with an effective tool to help them allocate limited resources towards effective transportation improvement projects.

8.3.3. CALTRANS' STRATEGIC GROWTH APPROACH

Caltrans's 2006 Strategic Growth Plan aims to decrease congestion, improve travel times, and improve safety, while accommodating population and economic growth, through innovations in transportation planning, project development and management, system management, and sustained coordination between the State and regional transportation agencies. The basic concepts promoted by this performance-driven and outcome-oriented management approach are more commonly depicted by the diagram in Figure 8-3. This diagram, often referred to as the Mobility Pyramid, represents the potential strategies that may be used to improve mobility within a corridor. System monitoring and evaluation provide the base of the pyramid. System maintenance and preservation then represent the next level. Smart land use, demand management, and value pricing strategies make up the third level, while Intelligent Transportation Systems, traveler information, traffic control systems, and incident management systems make up the fourth level. The fifth level includes operational improvements, while system expansion and completion represent the top of the pyramid. Acting as a complement to these various strategies is the need to prevent and/or reduce the risk of accidents.

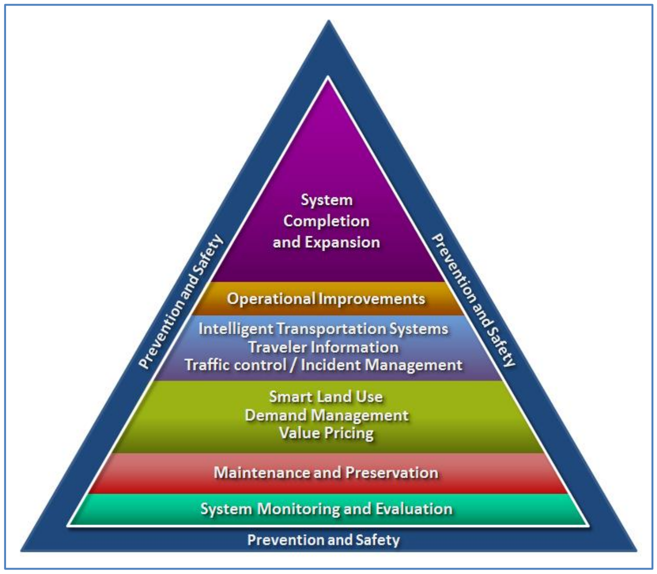

Figure 8-3 – Caltrans Mobility Pyramid

The Mobility Pyramid emphasizes that investment decisions targeting strategies higher up in the pyramid cannot be deployed effectively without a good foundation from the strategies below. System monitoring and evaluation are considered foundational strategies upon which all other strategies are built. Above this layer, the strategies are organized not according to their importance but to their interdependence. At each layer, the ability to improve system operations is viewed as being dependent on the investments in the strategies in lower layers. A key premise of the Strategic Growth Approach is that coordinated investments in the various strategies shown in the Mobility Pyramid can yield significant improvements in congestion relief, system reliability, safety, and productivity.

The ICM system concept follows the Strategic Growth Approach by considering how strategies from various layers of the pyramid can be used collectively to improve system operations, performance, and safety. The concept further recognizes the foundational importance of adequate system monitoring and evaluation by dedicating significant attention to how to improve system awareness using new information sources and new evaluation and forecasting capabilities.

8.3.4. CALTRANS' SMART MOBILITY 2010 FRAMEWORK

Caltrans' Smart Mobility 2010 Framework was developed to respond to today's transportation challenges with new concepts and tools. It lays out a vision for developing a new approach to transportation that is multi-modal, sustainable, and integrated with land use, and which attempts to address the following needs:

- California's mandate to find solutions to climate change and reduce greenhouse gas emissions.
- The desire to reduce per capita vehicle miles traveled.
- The demand for a safe transportation system that gets people and goods to their destinations.
- The commitment to create a transportation system that advances social equity and environmental justice.

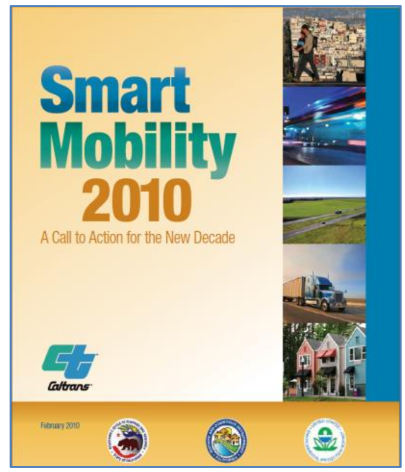

Figure 8-4 – Smart Mobility 2010

The following express the priorities and values of the framework:

- **Location Efficiency:** Integrate transportation and land use to achieve high levels of non-motorized travel and transit use, reduced vehicle trip making, and shorter average trip length, while providing a high level of accessibility.
- **Reliable Mobility:** Manage, reduce, and avoid congestion by emphasizing multi-modal options and network management through operational improvements and other strategies. Provide predictability and capacity increases focused on travel that supports economic productivity.
- **Health and Safety:** Design, operate and manage the transportation system to reduce serious injuries and fatalities, promote active living, and lessen exposure to pollution.
- **Environmental Stewardship:** Protect and enhance the State's transportation system and its built and natural environment; act to reduce greenhouse gases contributing to global climate change.
- **Social Equity:** Provide mobility for people who are economically, socially or physically disadvantaged to support their full participation in society; design and manage the transportation system in order to distribute its benefits and burdens equitably.
- **Robust Economy:** Invest in transportation improvements—including operational improvements—that support the economic health of the State and local governments, the competitiveness of California's businesses, and the welfare of California residents.

Smart Mobility aims to coordinate many of Caltrans' existing activities with the activities of other public and private organizations by introducing Smart Mobility principles into the following activities:

- Planning and programming activities.
- Development of standards and guidelines.
- Implementation of transportation projects and programs.
- Implementation of development and conservation projects and programs.
- Decision support activities.
- Evaluation of performance measures.
- Coordination of activities among operating and management agencies.

8.3.5. CONTINUOUS TRAVELER CONNECTIVITY

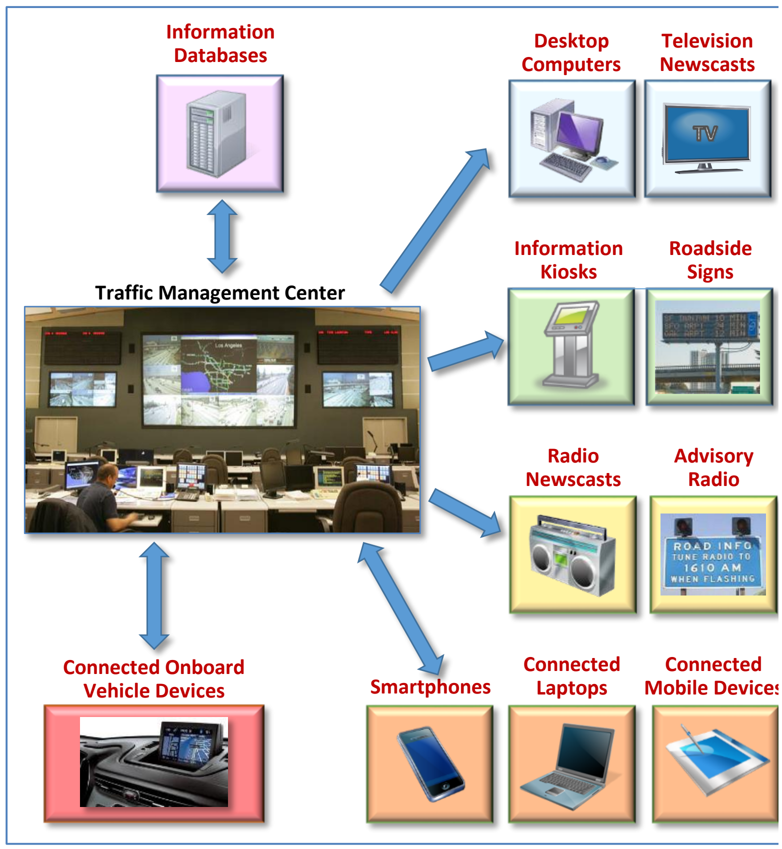

Figure 8-5 – Communication Capabilities with Travelers

Wireless technology improvements are not only creating new ways to collect information but also to disseminate it. Existing traveler information systems have been designed primarily to provide pre-trip information, as well as limited, context-specific en-route information via changeable message signs, highway advisory radios, and information kiosks. However, the increasing use of smartphones and connected mobile devices is providing a nearly continuous capability to communicate with travelers. Connected devices allow travelers to stay continuously abreast of current travel conditions. This empowers them to adjust their travel plans in response to unexpected events or incidents. It also enables them to become probe data collectors and to supply information systems with richer data. On the other side of the system, transportation system managers are also provided with the ability to communicate more quickly with en-route travelers, and, thus, to implement more proactive travel demand management strategies.

The prevalent use of connected devices facilitates not only the dissemination of information from TMCs to travelers but also information exchanges among travelers to exchange information about their travel experiences. Travelers may use social networks or specialized mobile applications to inform other travelers about unusual delays they are experiencing or have experienced along a particular road or transit route, thus triggering other individuals to avoid the facility. They may also use their connection to provide information to crowd sourcing applications. If adequately used, this continuous ability to exchange information can transform travelers from mere information recipients to active participants in the operation of transportation networks.

8.3.6. EMERGING PROBE VEHICLE DATA COLLECTION CAPABILITIES

Technological improvements in wireless communication are opening up new data collection capabilities. One key emerging capability is the ability to track vehicle movements through a network. This not only offers the opportunity to collect information about trip origins and destinations, but also about traffic conditions on individual roads.

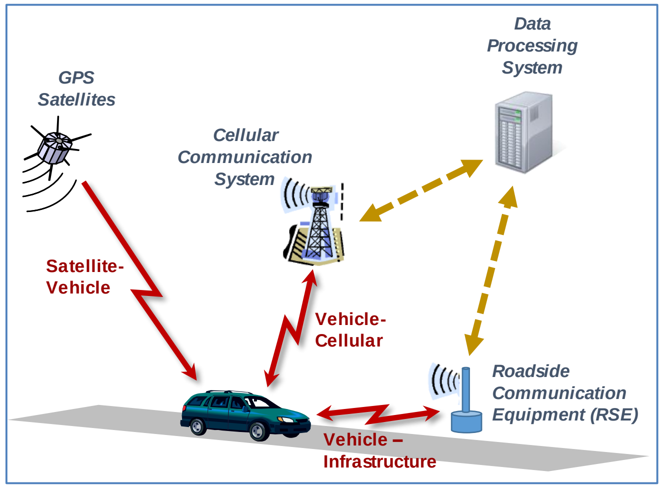

Figure 8-6 – Probe Data Collection

The following are examples of approaches that could be used to support vehicle tracking and collection of data from probe vehicles:

- **Radio Frequency Identification (RFID) tracking:** This technique tracks when vehicles equipped with unique RFID tags pass near dedicated roadside readers. Comparing detection time stamps from various readers makes it possible to track the movement of a particular vehicle and to estimate travel times. However, it does not reveal what a vehicle does between two stations. RFID tracking has been used for many years by toll authorities to monitor travel times and characterize travel patterns. Since RFID tags are associated with a specific user, the anonymity of travelers is typically preserved by encrypting and regularly dumping personal information in the datasets used for traffic performance assessment.
- **GPS-based tracking:** This technique tracks the location of GPS-equipped devices by calculating the time the GPS signal takes to travel between the device and an array of geostationary satellites. It allows tracking the position of devices with relatively high accuracy (~50 ft.) on a second-by-second basis. Various private companies already use data collected by probe vehicles equipped with a GPS receiver or GPS-enabled smartphones to assess traffic flow conditions for mapping applications they offer. In some cases, the collected data is also made available for purchase to public transportation agencies or third-party information providers. However, since GPS data can be traced to specific devices, the information providers typically restrict data use or encrypt the personal data to protect the privacy of the device owners.
- **Bluetooth tracking:** This technique is similar to RFID tracking, except that it tracks signals emitted by Bluetooth-equipped devices instead of RFID tags. Since each Bluetooth device has a unique Media Access Control (MAC) address, the technique allows determining when a specific device passes in proximity of a reader. Comparing time stamps from various readers makes it possible to estimate travel times between the readers and to reconstruct travel patterns. Like RFID tracking, no information is obtained on movements between detection stations. In addition, since MAC addresses are not associated with a specific user, no personal data or information that could be used to identify the whereabouts of a specific person is captured. Privacy is often further ensured by immediately concealing upon receipt collected MAC addresses through encryption.

Users having remaining privacy concerns also have the ability to turn off the Bluetooth discovery function of their devices to prevent it from being detected.

- **Wi-Fi Tracking:** This technique is similar to Bluetooth tracking, except that it tracks pings sent out by Wi-Fi devices searching for wife network connection. This technique again enables tracking by time-stamping when specific MAC addresses are recorded at specific locations.
- **Cellular geo-location:** This technique determines the location of devices communicating with cellular phone towers by processing the characteristics of the communication signals received at individual towers. Position accuracy depends on the density of cellular towers and number of towers with which a device is in contact. While accuracy is typically lower than with GPS tracking, this technique may be sufficient for determining the road on which a vehicle is traveling or the origin and destination zones of a trip. Because cellular geo-location relies on infrastructure owned and operated by private companies, access to this data is typically subject to agreement with individual cellular phone providers, as well as strong privacy-protection constraints.

While the use of probe data for assessing system operations remains relatively limited, mainly due to its novelty and lingering concerns about traveler privacy, it is expected to grow in popularity. Some information service providers are already attempting to incorporate probe data into their traffic information processing platforms. Ultimately, probe data utilization is strongly tied to the ability of travelers to perceive that noticeable benefits may be obtained by allowing their movements to be tracked, such as the ability to realize shorter or more reliable commute trips, while perceiving that their privacy rights are not violated.

It is anticipated that probe vehicle data may eventually replace information collected from traditional sources, such as in-pavement loop sensors or roadside sensors. However, before this occurs, the expectation is that probe data will primarily be used to *supplement* existing data sources.

8.3.7. QUICK-RESPONSE EVALUATION TOOLS

When faced with the need to respond to changing operational conditions, transportation system managers often rely on their experience and training to determine a course of corrective actions. While they often make appropriate decisions for addressing daily recurring congestion or frequently occurring incidents at known problematic locations, this approach does not guarantee that the best possible decisions are always adopted when facing situations that have not been previously encountered. While previous experience may help in assessing what may be needed to address a local problem, this experience may not be adequate to assess potential consequences at the network level or unexpected effects on other systems or jurisdictions.

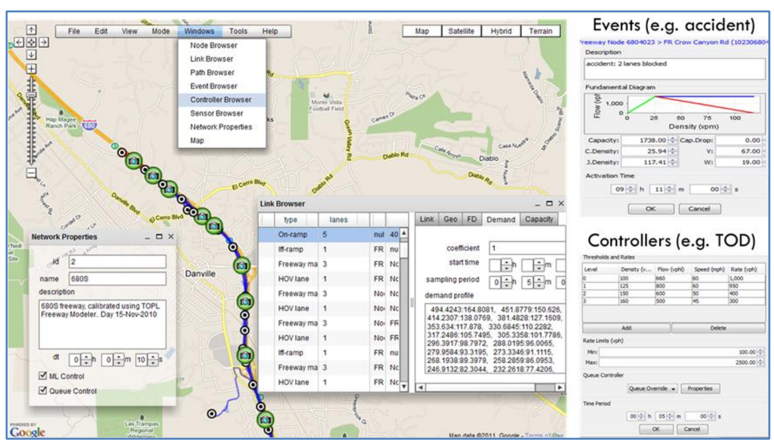

Figure 8-7 – Network Evaluation Tool

To help system operators and managers adequately respond to changing operational conditions, various agencies have recently sought to develop decision support tools providing recommended action plans based on analytical system evaluations. Examples of recently developed tools include:

- **Caltrans District 7 Event Management System** – This system helps operators determine responses to incidents, emergency closures, and major scheduled events. Based on information characterizing the location, time, type, and number of vehicles involved in the incident, a response plan is developed using rules formulated by experts in freeway management. Elements of the plan may include which changeable message sign to use, which messages to post, who should be contacted regarding the incident, etc.
- **US-75 ICM System (Dallas, Texas)** – This system uses a traffic simulation model capable of evaluating demand-supply interactions in large intermodal networks to determine traffic management actions to take to address congestion, incidents, and planned or unplanned events. There is no on-the-fly response plan generation. Only predefined response plans that have been agreed to by all corridor stakeholders are considered. A set of built-in rules determines which plans to evaluate, and a recommended plan to implement is identified based on simulation results covering the next hour of operation. Response strategies may include change in HOV/HOT access, early dissemination of traveler information, traffic diversion to frontage and/or parallel roads, mode diversion to transit, and parking management strategies.
- **I-15 ICM System (San Diego, California)** – Following the identification of an incident, event, or congestion, this system first uses a predefined set of rules to develop various response plans to address the identified problem. Control actions may include changing the metering rates of signals installed on freeway on-ramps, changing the timing plan in use at various signalized intersections along corridor arterials, changing the configuration of the freeway's high-occupancy toll lanes, and displaying travel advisories and/or detour recommendations on changeable message signs along the freeway. Following the development of a set of suitable plans, a traffic simulation model detailing the movements of individual vehicles on the freeway and nearby arterials is used to assess the performance of each plan over the next 60 minutes and to identify the most effective plan to implement.

The above systems all introduce significant and valuable new functionalities to support the management of transportation corridors. However, limiting factors remain associated with the various systems:

- In the Caltrans District 7 system, incident responses are entirely predefined. A specific set of conditions invariably lead to the selection of a specific response strategy, which results in a lack of flexibility to address new situations.
- In both the I-15 and US-75 ICM systems, simulation allows evaluating multiple response strategies and determining which offers the most promising prospects of achieving the desired effect. However, the use of simulation models considering the movements of individual vehicles imposes high computing requirements and long execution times in both cases that result in practical limits on the number of scenarios that can be evaluated. For the I-15 system, a powerful computer needs two to three minutes to conduct a 60-minute simulation. For the US-75 system, up to one minute is required to conduct a 30-minute evaluation. These simulation times create a need to develop carefully the rules leading to the identification of response scenarios. While more simulations can be executed by increasing the number of computers, this approach may not be within the operating budgets of individual agencies or even desire.

To expand evaluation capabilities, modeling approaches favoring the quick production of simulation results should be favored. This may imply a greater reliance on mesoscopic or macroscopic modeling approaches that do not necessarily model the movements of individual vehicles in detail. While some fidelity may be lost, the ability to produce simulation results more quickly would translate into an ability to evaluate more scenarios, and, thus, into the ability of traffic managers to perform more comprehensive assessments of the various strategies that may be implemented.

Another benefit of the quick-simulation modeling approach is to reduce the number of parameters that must be considered during model calibration. Instead of attempting to calibrate a large set of parameters designed to capture specific aspects of driver behavior, the calibration focuses on parameters commonly available to traffic managers, such as traffic flow, traffic speeds, flow density, and turning counts. The primary reliance on such parameters makes the calibration process more intuitive and amenable to individuals who may not be modeling and simulation experts.

8.3.8. PROMOTION OF PROACTIVE TRAFFIC MANAGEMENT APPROACHES

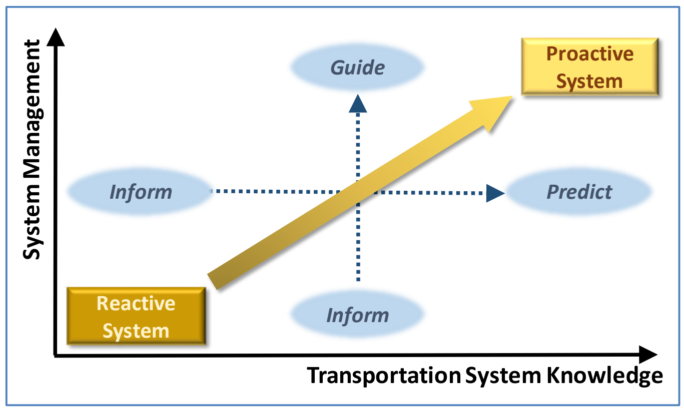

Figure 8-8 – Reactive vs. Proactive Systems

Transportation agencies have demonstrated in numerous instances that proactively managing transportation systems can reduce travel times, improve travel reliability, increase traffic throughput, and decrease crashes. For instance, instead of waiting for long vehicle queues to develop following the closure of a freeway lane due to an incident before implementing congestion-relief measures, remedial actions are implemented as soon as the problem is detected and its potential magnitude on system operations assessed. Establishing proactive management requires the capability not only to detect traffic conditions in reasonable time, but also to quickly predict how an event or incident may affect traffic operations. This requires strong partnership agreements between agencies involved in the operation of a corridor. The proposed ICM system supports this goal by seeking new ways of monitoring travel activities within transportation systems, developing fast corridor-based simulation evaluation tools, and promoting the coordination of activities among agencies involved in the operation of a corridor. The goal is to move from a system in which traffic data is used strictly to inform transportation managers, who then rely on their knowledge to implement a response strategy, to a system in which there is an increase in vaulable information used to predict near-future traffic conditions and to guide the selection of an appropriate response.

8.3.9. GRADUAL PATH TO INTEGRATED TRANSPORTATION MANAGEMENT

Currently, transportation corridors are typically managed using independent, or mostly independent, systems. Metering signals on freeway on-ramps, for example, are usually operated independently from traffic signals on neighboring arterials. Traffic signals along a corridor belonging to different agencies are also often operated independently from each other. This problem is further compounded by the fact that transportation agencies within a corridor often use different hardware or control systems within their respective jurisdiction, with some agencies using different control systems and hardware even within their own jurisdiction.

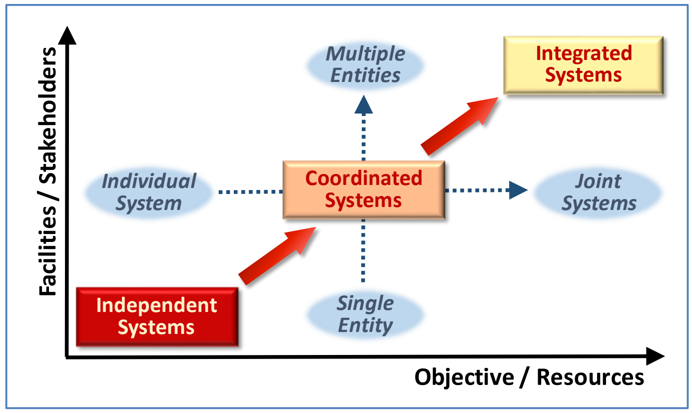

Figure 8-9 – Path to Integrated System

As previously indicated, the ultimate goal of ICM is to develop a full ICM system capable of addressing all the travel needs of all users of a transportation corridor. Instead of optimizing each system based on its own operational capabilities and potential interactions with other systems, multiple systems are optimized simultaneously based on overall, multi-modal corridor performance metrics. This means potentially implementing sub-optimal operation for a given system if this approach is deemed beneficial to overall corridor operations.

Considering the current operational environment, a realistic path to achieving the above goal is to first promote the benefits of operational coordination among existing systems before eventually focusing on developing integrated systems. This path is conceptually illustrated in the diagram of Figure 8-9. While the concepts of system coordination and system integration may appear similar at a first glance, they have subtle differences:

- **System coordination** refers to the process by which the operations of individual systems are optimized in relation to the operation of other systems, but without sacrificing the operational independence of each system. In this case, each system is typically optimized individually using system-specific metrics.
- **System integration** goes a step further from coordination by bringing together various subsystems into a single operating system. In this case, individual systems are typically optimized together using shared corridor-wide metrics encompassing all relevant transportation modes.

Within the above path, initial system development would focus on enhancing existing systems and coordinating their operations wherever possible. Subsequent phases would gradually shift the focus to developing new system integration resulting in a single operating environment. For example, Table 8-2 outlines how such a staged approach could lead to the development of a comprehensive, multi-modal traffic management system.

Table 8-2 – Example of a Path towards System Integration

	Existing System	**Intermediate Coordinated Systems**	**Final Integrated System**
Goals	• Minimum coordination among agencies, except transit schedule planning (for connection and events).	• Coordinated use of designated system capacities/resources to accommodate selected demands, or prioritized needs under prescribed circumstances.	• Integrated system to manage the entire network and optimally accommodate all demands, or prioritized needs under prescribed circumstances.
Performance Assessment	• Primarily based on mode or system-specific metrics	• Primarily based on mode or system-specific metrics, but with some considerations for impacts on other modes or systems.	• Based on corridor-wide performance metrics encompassing all travel activities.
Operational Integration	• Independent operations across modes, with the exception of transit schedule planning • Some signal synchronization across key regional corridors	• Coordinated operation across modes and networks. • Comparable performance measures across networks. • A portion of the system resources are managed based on localized demands, conditions, and needs. • Localized system response for incident conditions. • Operations may be implemented using a real-time closed-loop approach, with pre-approved coordinated operation plans among corridor stakeholders. • Users are offered travel options through real-time information and incentives.	• Integrated operation across modes and networks. • Synergistic performance measures across networks. • Overall system resources are optimally managed based on corridor-wide demands, conditions, and needs. • System-level response for incident conditions. • Majority of operations are done in real time. • Users actively participate in system operations, enticed by system-wide pricing/incentives.
Technological Integration	• Independent systems.	• Portions of system are integrated, but most of the functions are not. • Data collected separately and shared among stakeholders and first responders. • While hardware and software components are separated, some functions are coordinated through interfaces. • Integrated tools for planning, design, and evaluation are not available.	• Integrated data gathering, distribution, and processing. • Hardware and software can be distributed components, while functions and processes are shared. • System interfaces and data exchange/communication protocols are standardized. • Functional expansions are done through consideration of integrated system. • Integrated tools for planning, design, and evaluation are available.
Institutional Integration	• Each agency is responsible for its own operations.	• Interagency agreements for supporting coordinated operations.	• Interagency agreements for facilitating collaborative / integrated operations.

8.4. POTENTIAL CORRIDOR IMPROVEMENT STRATEGIES

Potential ICM improvement strategies fall into the following categories:

1. **Improving transportation system monitoring –** Expanding the collection of traffic and system operational data from freeways, arterials, transit systems, and possibly parking facilities, to improve our understanding of how individual system elements are operating.
2. **Improving travel demand monitoring –** Expanding the collection of information for characterizing travel patterns in a corridor, such as data identifying routes commonly followed by passenger cars and trucks, or identifying vehicles' origin or destination zones.
3. **Enhancing information dissemination** – Making relevant traffic and operational data available to system users through improved information exchanges between transportation systems, enhanced traveler information systems, and information clearinghouses to be implemented for all corridor stakeholders, including information service providers and other value-added entities. An overarching goal is to provide system users with reliable real-time and forecasted data.
4. **Improving traffic operations** – Improving how the existing road network is being used to satisfy the travel needs of individuals and goods. This potentially includes improvements in how ramp meters are operated, the operation and coordination of traffic signals along arterials, enforcement practices, and the development of coordinated maintenance schedules based on traffic operational needs across jurisdictions.
5. **Increasing the use of public transportation** – Improving how public transit systems are operated and managed to increase their attractiveness and viability for ICM system users.
6. **Influencing travel demand** – Implementing strategies enticing travelers to alter their travel mode, time of travel, and/or planned itinerary with the underlying objective of improving overall system operations.
7. **Improving responses to incidents/events** – Implementing procedural and operational strategies to reduce the impacts of incidents, planned road closures, and special events on corridor performance.
8. **Enhancing existing infrastructure** – Implementing strategies to provide additional capacity or operational improvements through infrastructure changes. The primary focus here is on small-scale/low-cost projects supporting the implementation of other strategies, such as a ramp widening to implement an HOV bypass lane, allowing shoulder running at particular instances, adding a park-and-ride lot within an existing facility, etc. Larger projects that have already been approved for implementation may also be considered as part of the ICM system, as well as any project proposed as highly desirable by corridor stakeholders and for which funding is already available or highly likely.

For each of the above categories, Table 8-3 identifies specific strategies that can be implemented to enhance corridor operations and how each strategy relates to the ICM system goals that have been previously listed in Table 8-1. All the listed strategies address at least one of the system goals, with many addressing several goals.

Table 8-3 – Potential Corridor Improvement Strategies

ID	Strategy	Improve System Awareness	Promote Collaboration	Improve Incident Response	Improve Travel Reliability	Increase Corridor Mobility	Improve Traveler Information	Facilitate Transit Movements	Reduce Emissions	Improve Corridor Safety
1.0	**Improving Transportation System Monitoring**									
1.1	Enable the status of control and informational devices (signal controllers, CMS, etc.) to be monitored in real time	●	○	●	○	○	●	○	○	○
1.2	Provide the ability to collect in real time traffic volumes measured by freeway and arterial sensors	●	○	●	○	○	●	○	○	○
1.3	Provide the ability to measure in real time turning proportions at intersections and freeway diverge points	●	○	○	○	○	●	○	○	○
1.4	Provide the ability to measure in real time travel times between specific locations	●	○	●	○	○	●	●	○	○
1.5	Enable traffic and travel demand monitoring systems to collect probe vehicle data	●	○	○	○	○	●	●	○	○
1.6	Integrate real-time transit operational data (bus location, schedule adherence, etc.) into corridor monitoring system	●	○	○	○	○	●	●	○	○
1.7	Integrate real-time parking operational data (parking availability, pricing) into corridor monitoring system	●	○	○	○	○	●	●	○	
1.8	Integrate weather information into corridor monitoring system	●	○	○	○	○	●	○	○	●
1.9	Integrate traffic data available from 3rd party information service providers (e.g., INRIX, Navteq)	●	○	○	○	○	●	○	○	○
1.10	Integrate user generated content that can be retrieved from 3rd party applications (e.g., Waze)	●	○	○	○	○	●	○	○	○
2.0	**Improving Travel Demand Monitoring**									
2.1	Project near-future traffic flow demand by comparing real-time operational data to historical data	●	○	●	○	○	○	○	○	
2.2	Use probe data to assess origin-destination flow patterns	●	○	○	○	○	○	○	○	○
3.0	**Enhancing Information Dissemination**									
3.1	Establish data sharing capabilities among agencies operating within a corridor	●	●	●	○	○	●	○	○	○
3.2	Establish a corridor data clearinghouse / data exchange	●	●	●	○	○	●	○	○	○
3.3	Enable third-party information service providers to access multi-modal travel data collected by the ICM system	●	●		○	○	●	●	○	○
3.4	Provide real-time traffic data to traveler information systems	●	●	○	●	●	●	○	○	○
3.5	Provide traffic and travel demand projections to travelers and information service providers	●	●	○	○	●	●	○	○	○
3.6	Deploy changeable message signs along freeways		●	●	●	●	●	●	●	○
3.7	Deploy dynamic route guidance system along arterials		●	●	●	●	●	●	●	○
3.8	Expand existing Highway Advisory Radio (HAR) system		●	●	●	●	●	●	●	○
3.9	Expand 511/telephone traveler information services	○	●	●	●	●	●	●	●	○
3.10	Develop comprehensive web-based traveler information applications	●	●	●	●	●	●	●	●	○
3.11	Develop mobile traveler information applications that can be accessed from smartphones and other mobile devices	●	●	●	●	●	●	●	●	○
4.0	**Improving Traffic Operations**									
4.1	Develop a capability to evaluate near-future impacts of proposed corridor management strategies	●	●	●	●	●	●	●	●	

● Directly supports goal ○ Indirectly supports goal

Table 8-3 – Potential Corridor Improvement Strategies (cont'd)

ID	Strategy	Improve System Awareness	Promote Collaboration	Improve Incident Response	Improve Travel Reliability	Increase Corridor Mobility	Improve Traveler Information	Facilitate Transit Movements	Reduce Emissions	Improve Corridor Safety
4.2	Develop a decision-support tool providing corridor managers with recommended courses of actions	●	●	●	●	●		●	●	●
4.3	Provide traffic-responsive or adaptive ramp metering	●	●	●	●	●		○	●	●
4.4	Coordinate ramp metering operations across adjacent freeway on-ramps	●	●	●	●	●		○	●	●
4.5	Coordinate ramp metering operations with nearby arterial traffic signals		●	●	●	●		○	●	●
4.6	Coordinate traffic signal operations across jurisdictions		●	●	●	●		○	●	●
4.7	Develop specialized traffic signal control plans to deal with special events, specific types of incidents			●	●	●		○	●	●
4.8	Implement traffic-responsive signal control (plan selection) along arterials		●	●	●	●		○	●	●
4.9	Implement traffic-adaptive/real-time signal control system along arterials			●	●	●		○	●	●
4.10	Adjust HOV access restrictions based on observed/projected traffic conditions			●	●	●		○	●	○
4.11	Implement congestion warning system along freeways and/or arterials			○	●			○	●	●
4.12	Implement variable advisory speed system along freeways and/or arterials			○	○	●		○	●	●
4.13	Implement off-ramp queue warning system along freeways			○	●			○	●	●
4.14	Enable use of freeway shoulders as temporary traffic lanes (where permitted by roadway design)			●	●	●		○	●	
4.15	Enable use of freeway off-ramp shoulders as temporary traffic lanes			●	●	●		○	●	●
4.16	Implement dynamic merge control at freeway on-ramps (e.g., closing of right lane on mainline to improve inflow)			●	●	●		○	●	●
4.17	Implement dynamic turn restrictions/lane use at signalized intersections			●	●	●		○	●	○
4.19	Implement reversible lane system along arterials			●	●	●		○	●	○
4.18	Implement dynamic curb lane parking restrictions along arterials to provide additional traffic lane when needed			●	●	●		○	●	●
4.20	Implement automated enforcement of traffic signals (e.g., red-light-running cameras)							○		●
4.21	Implement automated enforcement of traffic speeds				○			○		●
4.22	Coordinate maintenance and construction activities across jurisdictions		●		●	●		○	●	●
5.0	**Increasing Public Transportation Ridership**									
5.1	Implementation of transit signal priority for transit vehicles at signalized intersections		●		●	●		●	●	
5.2	Implement transit-only lanes along select arterials or at select intersections		●		●	○		●	●	
5.3	Adjust transit service frequency based on observed/projected travel demand and traffic conditions		●	●	●	●		●	●	
5.4	Promote coordination of transit schedules among agencies to facilitate transfers between various modes		●	●	●	●		●	●	
5.5	Provide dynamic connection protection at key transit transfer points		●	●	●	●		●	●	

● Directly supports goal ○ Indirectly supports goal

Table 8-3 – Potential Corridor Improvement Strategies (cont'd)

ID	Strategy	Improve System Awareness	Promote Collaboration	Improve Incident Response	Improve Travel Reliability	Increase Corridor Mobility	Improve Traveler Information	Facilitate Transit movements	Reduce Emissions	Improve Corridor Safety
5.6	Provide on-demand transit ride service		●	○	●	●		●	●	
5.7	Implement dynamic ridesharing service		●	○	●	●		●	●	
6.0	**Influencing Travel Demand**									
6.1	Impose/remove truck travel restrictions based on observed traffic conditions		○	●	●	●			●	●
6.2	Recommend alternative routes around incidents / severe congestion			●	●	●	●	●	●	
6.3	Provide comparative travel time estimates for motorized travel along alternate routes			●	●	●	●	○	●	
6.4	Provide comparative travel time estimates for travel on alternate transportation modes (e.g., car, transit)			●	●	●	●	●	●	
6.5	Suggest alternative trip departure times offering travel time reductions with each route query			●	●	●	●	●	●	
6.6	Provide dynamic guidance to parking facilities with open spaces		●	●		●	●	●	●	○
6.7	Use dynamic pricing to influence demand for HOT lanes			●	●	●		●	●	
6.8	Use dynamic pricing to influence the demand for parking		●	●	●	○		●	●	
6.9	Use of incentives to promote the use of alternate travel mode or changes in when a trip initiated			●	●	●	●	●	●	
7.0	**Improving Response to Incidents**									
7.1	Enhance the capture of information characterizing incidents and describing response actions taken	●	○	●	○	○	●	○		○
7.2	Develop joint, coordinated multi-agency incident response processes		●	●	●	●		●	●	●
7.3	Provide alternate routing information on freeway changeable message signs		●	●	●	●	●	●	●	
7.4	Provide dynamic trailblazer signs along arterials to guide traffic back to the freeway		●	●	●	●	●	●	●	
7.5	Expand existing Freeway Service Patrol program to further expedite the removal of traffic impediments		●	●	●	●		○	●	○
7.6	Implement transit service route deviations around major incidents		●	●	●	●		●	●	
7.7	Implement additional transit services to alleviate the impacts of major incidents		●	●	●	●		●	●	
7.8	Allow travelers to use private parking facilities as temporary park-and-ride facilities through agreement with facility operators		●	●	●	●		●	●	
7.9	Develop signal timing plans designed to minimize queues		●	●	●	●		○		●
7.10	Provide signal preemption to emergency vehicles at signalized intersections		●	●		○				●
8.0	**Enhancing Existing Infrastructure**									
8.1	Add HOV bypass lanes on freeway ramps				●	○		●	●	
8.2	Convert existing HOV lane(s) into HOT lane(s)				●	●		○	●	
8.3	Implement minor improvements (e.g., lane restriping) to interchanges/intersections to improve flow operations				●	●		○	●	
8.4	Implement minor Improvements to intermodal stations to facilitate drop off/pick up activities		●		●	●		●	●	

● Directly supports goal ○ Indirectly supports goal

8.5. STRATEGIES INTENTIONALLY EXCLUDED

While Table 8-3 lists a wide array of potential corridor improvement strategies, strategies belonging to the following categories were excluded intentionally from consideration:

- Large infrastructure projects
- Connected vehicle applications relying on vehicle-to-vehicle communication

8.5.1. LARGE INFRASTRUCTURE PROJECTS

Capital projects requiring significant right-of-way acquisition, the building of complex new infrastructure, significant funding, or a lengthy and complex approval process were not considered as viable solutions for the proposed ICM system. Examples of potential corridor improvement strategies that were excluded include:

- Building new roadways within the corridor
- Widening the freeway mainline to add new general purpose or HOV lanes
- Rebuilding freeway interchanges
- Expanding existing light-rail and heavy rail transit services beyond the currently planned Montclair terminus for Phase 2B of the Gold Line Extension
- Building new multi-level parking garages to increase park-and-ride opportunities

8.5.2. VEHICLE-TO-VEHICLE COMMUNICATION APPLICATIONS

While the proposed ICM system attempts to leverage emerging connected vehicles capabilities, not all applications enabled by emerging communication capabilities were considered. Applications enhancing transportation system monitoring and the dissemination of information to travelers before or during a trip were generally considered. However, applications to improve traffic flow operations and/or safety through vehicle-to-vehicle communication, and to some extent infrastructure-to-vehicle communications, were generally excluded on the rationale that their development typically falls under the responsibility of vehicle manufacturers. Examples of applications that were excluded include:

- Cooperative merge assistance
- Intersection movement assist
- Intersection collision avoidance
- Advanced signal timing change warning
- Emergency brake light warning
- Forward collision warning
- Blind spot and lane change warning

While the above applications would likely provide benefits, these benefits would be more closely tied to vehicle improvements than improvements in how transportation systems are operated and managed by their responsible agencies.

8.6. POTENTIAL OPERATIONAL ICM SYSTEM FRAMEWORK

Figure 8-10 illustrates of how a fully developed ICM system could work. The large blue box at the bottom of the diagram represents the transportation corridor being managed. Within the box, the seven smaller blue boxes show the various transportation system elements. The primary functions of the proposed ICM system, as outlined in the figure, are as follows:

- **Data Collection / Validation / Fusion** – System operations start with a need to collect comprehensive and reliable information about how individual elements are operating. This is illustrated by the gray boxes representing various data streams from the Transportation Corridor into the Data Collection/Validation/Fusion box. This need includes collecting information from traffic sensors, control devices, probe vehicles, transit monitoring systems, parking monitoring systems, and user-generated data through mobile applications and social networks on a 24-hour/7-day-a-week basis. Information about active incidents, weather, construction and maintenance schedules, and other planned events may also be collected. All collected data must further be validated prior to being used to ensure that no erroneous information is used in system evaluations. Data processing may also involve the application of data fusion algorithms designed to address potential discrepancies among data collected from various sources and gaps in collected data.
- **System Operational Assessment** – Following data collection, available data would be used to assess the performance of the various system elements. This may be accomplished using deterministic algorithms, stochastic analyses, and/or simulation, enabling the estimation of various performance measures of interest covering all operational modes. A key objective of the evaluations would be to determine how efficiently each system is being used, identify operational problems, and determine, if possible, the source and potential cause of each problem.
- **Determination of Asset Availability** – Prior to conducting any strategy evaluation, an inventory of available assets must be conducted to determine which assets may be used to influence system operations or travel demand. While this step may appear trivial, it must be understood that specific assets may not always be available. For instance, an Amber Alert may result in the inability to use Caltrans-operated freeway CMS to convey traveler information to motorists. Technical glitches may also result in a temporary inability to communicate with a traffic signal controller. In both cases, there would be no need to evaluate strategies based on unavailable assets.
- **Evaluation and Selection of Management Strategies** – At every evaluation cycle, available management strategies would be evaluated to determine their effectiveness in addressing the identified operational problems. As indicated above, only the strategies that can physically be implemented would be evaluated. Evaluations would be conducted by a Decision Support System (DSS) drawing strategies from rules or playbooks describing potential supply-side and demand management solutions. Figure 8-11 shows a conceptual representation of the DSS operations. The DSS would be designed to operate in a real-time environment. It would use various processes to evaluate current system operations, determine the near-term impacts of individual strategies or groups of strategies, and provide recommendations on which strategies to implement. Depending on system setup and capabilities, these evaluations could be conducted every 5, 10, or 15 minutes.
- **Strategy Execution** – This step involves converting the actions associated with the selected management strategy into specific commands that can be understood by the various control elements and assets involved in the implementation of the strategy.

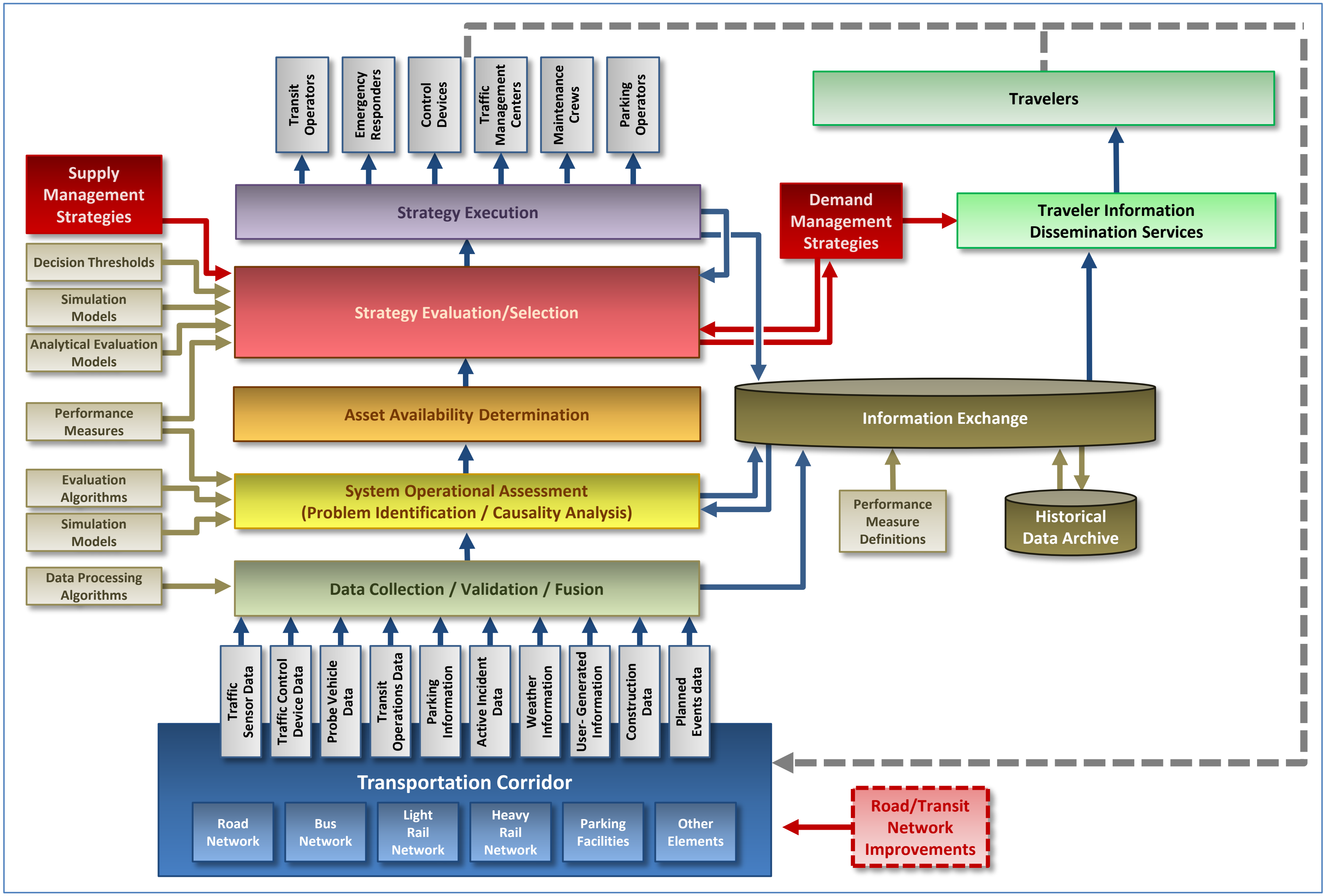

Figure 8-10 – Functional View of Fully Developed ICM System

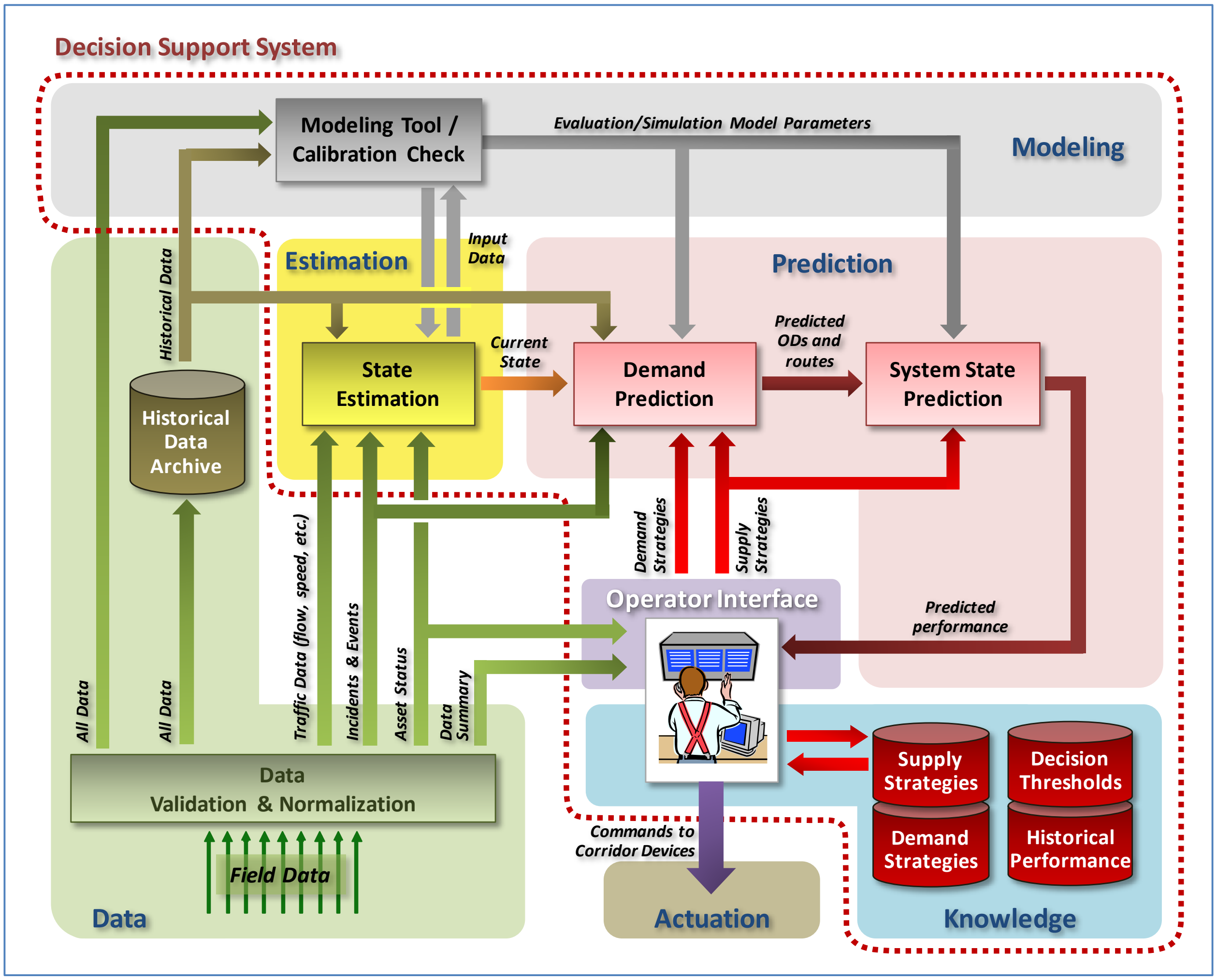

Figure 8-11 – Operational Concept for Decision Support System

- **Information Warehousing** – A key element of any ICM system is the facilitation of data exchange among corridor stakeholders. To help support this objective, the system would send all shareable information to a data exchange that could be accessed by the operators of individual systems, as well as information service providers. The exchange would also have access to a historical database and have the task of sending new information to the database for storage.
- **Traveler Information Applications** – Another key concept is the ability to communicate travel information and trip suggestions to system users, both before they start a trip and while traveling. This is represented by the boxes on the upper right side of Figure 8-10 illustrating information flowing from the data exchange to travelers via 511/public travel information systems and third-party information service providers. These boxes not only include traditional value-added applications, in which enriched travel information is provided to travelers following various data processing, but also social applications enabling travelers to communicate transportation information directly between them.
- **Feedback Control Loop** – The last key element is the control feedback loop represented by the dotted arrow pointing back to the transportation network at the bottom of the figure. This feedback loop represents the effects that implemented traffic management strategies and

disseminated travel information may have on system operations. The expectation is that system operations would be periodically re-evaluated, for instance every 5, 10 or 15 minutes, to assess whether changing operating conditions warrant changes in the active traffic management strategy or information sent to travelers.

In the above framework, the Decision Support System (DSS) is the heart of the corridor management system. As indicated above, this system would be responsible for evaluating and selecting on a real-time basis the management strategies to implement. As illustrated in Figure 8-11, key functionalities of the DSS would include:

- **State Estimation** – Estimation of the efficiency of current system operations based on an analysis of real-time data provided by various monitoring systems, archived historical data, and results from the application of analytical and/or simulation models.
- **Demand and State Prediction** – Determination of near-future system operations and performance based on projected changes in traffic demand and the implementation of various combinations of demand management and/or supply management strategies.
- **Operator Interface** – Communication of strategy evaluations results to system operators for final strategy assessment and selection and/or implementation approval.
- **Knowledge Development** – Archiving of strategy selection and evaluation results for future analysis and refinement.
- **Modeling Tool Maintenance** – Periodic update of the calibration parameters in analytical and simulation tools to enable the tools to track observed changes in operational conditions and/or traffic behavior.

8.7. POTENTIAL SYSTEM OUTPUTS

Outputs from the proposed ICM system include all operational commands and value-added information that may be produced by the analysis of collected data, evaluation of system performance, system forecasts, and selection of a set of traffic and demand management strategies to pursue. Depending on the specific configuration of the implemented system, key outputs may include:

- Data characterizing current transportation system operations sent to the information exchange:
    - Observed travel demand on roadway segments/routes (origin-destination flows, split ratios at freeway off-ramps, turning movements at intersections, etc.)
    - Roadway network performance metrics (traffic flows, delays, densities)
    - Transit network performance metrics (bus delays, ridership)
    - Active incidents (location, severity, anticipated/observed duration)
    - Status of parking facilities (parking availability, parking rate)
    - Traveler response rate to disseminated information

- Operational forecasts sent to the information exchange:
    - Projected travel demand on roadway segments/routes
    - Projected transit ridership
    - Projected roadway conditions

- Projected transit system performance
- Projected parking facility utilization

- Traffic-related operational commands:
    - Increase/decrease metering rates on freeway ramps and connectors
    - Alteration/replacement of active traffic signal control plans along arterials
    - Messages to display on changeable message signs
    - Increase/decrease of active toll price on bridges and/or HOT lanes
    - Increase/decrease of active parking price
    - Opening/closing traffic lanes to specific vehicles (trucks, non-HOV vehicles, buses, etc.)
    - Command to change lane utilization displays (for instance, turning on a no left-turn sign)

- Transit-related operational commands:
    - Request for increase/decrease in transit service
    - Request for transit connection protection
    - Request for on-demand transit trip
    - Transit signal priority requests (green extension, red truncation)
    - Activation/deactivation of transit signal priority capability

- Traveler information derived from various system operations
    - Trip time estimates
    - Recommended detour around incidents/congestion
    - Guidance to parking facilities
    - Alternate route/mode comparisons
    - Incident/congestion warnings
    - Incentives to alter travel time/travel mode

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9. CORRIDOR STAKEHOLDERS

Stakeholders in the I-210 Connected Corridors Pilot include agencies and institutions having a direct interest in how the system is to be operated, as well as entities having an interest in how the system is to affect travel conditions within the corridor. Table 9-1 lists the key stakeholders groups, categorized according to the following schema:

- **Freeway operators** – Entities managing freeway traffic
- **Roadway operators** – Entities managing local arterials and regional highways
- **Rail transit operators** – Entities providing commuter rail and light-rail transit services
- **Bus transit operators** – Entities providing fixed-route transit services
- **Paratransit operators** – Entities providing on-demand transit services
- **Parking operators** – Entities managing parking garages and parking lots within the corridor
- **Motorist aid services** – Entities responsible for providing aid to stranded motorists
- **Emergency responders –** Entities tasked with responding to emergency incidents and situations
- **Information providers** – Entities using information produced by the ICM system to generate and distribute value-added travel information for use by corridor travelers
- **Information consumers** – Entities using information produced by the proposed ICM system to help plan their movements within the managed corridor
- **Local transportation planning** – Agencies planning transportation system development at a local level
- **Regional planning** – Agencies forecasting regional travel demand patterns and developing long-range transportation improvement plans
- **Technical/Policy Advisor –** Entities involved in developing and applying regional standards and policies
- **Application developer and system integrators** – Entities responsible for the developing, and possibly operating, devices and systems used within the corridor

For each identified stakeholder, Table 9-2 provides a detailed listing of the various divisions or groups within the entity that have a stake in the project. Within each stakeholder group, the leading entity is listed first. More information about each stakeholder is provided in the subsections that follow.

Table 9-1 – Roles of I-210 Pilot Stakeholders

Stakeholder	Freeway Operator	Roadway Operator	Rail Transit Operator	Fixed-Route Bus Transit Operator	Dial-a-ride/Paratransit Operator	Parking Operator	Motorist Aid Services	Emergency Responder	Information Provider	Information Consumer	Local Transportation Planning	Regional Planning	Technical/Policy Advisor	Application Developer/Integrator
Caltrans – District 7	●	●				●			●	●	●	●	●	
Caltrans – Headquarters													●	
Los Angeles County Metropolitan Transportation Authority			●	●		●	●		●	●		●	●	
Los Angeles County		●			●	●		●	●	●	●	●	●	
City of Pasadena		●		●	●	●		●	●	●	●			
City of Arcadia		●			●	●		●	●	●	●			
City of Monrovia		●			●	●		●	●	●	●			
City of Duarte		●		●		●			●	●	●			
Foothill Transit				●					●	●				
Private parking operators						●			●	●				
LA County Service Authority for Freeway Emergencies (LA SAFE)							●	●	●	●				
California Highway Patrol (CHP)							●	●	●	●				
Southern California Association of Governments (SCAG)												●	●	
San Gabriel Valley Council of Governments (SGVCOG)												●	●	
Corridor travelers									●	●				
Commercial Fleet Operators									●	●				
Traffic information providers									●	●				
Consulting firms and equipment vendors														●
University of California, Berkeley – PATH Program													●	●
US Department of Transportation (USDOT)													●	

Table 9-2 – Key Stakeholder Subgroups

Stakeholder	Subgroups
Caltrans – District 7	• Division of Operations • Division of Planning • Division of Maintenance • Division of External Affairs
Caltrans – Headquarter7s	• Division of Traffic Operations • Division of Transportation Planning • Division of Maintenance • Division of Research, Innovation and System Information
Los Angeles County Metropolitan Transportation Authority (Metro)	• Metro Bus • Metro Rail • Metro Freeway Service Patrol • Highway Program • Transportation Planning
Los Angeles County	• Department of Public Works • Sheriff's Department • Fire Department • Department of Coroner

City of Pasadena	• Department of Transportation
	• Department of Public Works
	• Pasadena Area Rapid Transit System
	  - Department of Transportation Staff
	  - Contracted Vehicle Operator (First Transit)
	• Pasadena Police Department
	• Pasadena Fire Department
	• Transportation Advisory Commission

City of Arcadia	• Engineering Division, Development Services Department • Arcadia Transit • Public Works Services Department • Arcadia Police Department • Arcadia Fire Department • Traffic Advisory Committee
City of Monrovia	• Department of Public Works • Traffic Safety Committee • Monrovia Transit • Monrovia Police Department
City of Duarte	• Public Works Department • Traffic Safety Commission • Duarte Transit
Foothill Transit	• Foothill Transit Management Staff • Contracted Fleet Operators (Veolia, First Transit)
Los Angeles Service Authority for Freeway Emergencies (LA SAFE)	• Call Boxes • 511 Traveler Information System
California Highway Patrol (CHP)	• *No specific subgroup identified*
Southern California Association of Governments (SCAG)	• Transportation Committee • Planning & Programs Department

Table 9-2 – Key Stakeholder Subgroups (cont'd)

Stakeholder	Subgroups
San Gabriel Valley Council of Governments (SGVCOG)	• Transportation Committee
Private parking operators	• *No specific subgroup identified*
Traffic information providers	• *No specific subgroup identified*
Corridor Travelers	• Motorists • Transit Riders • Cyclists and Pedestrians
Commercial Fleet Operators	• *No specific subgroup identified*
Consulting firms and equipment vendors	• *No specific subgroup identified*
University of California, Berkeley – PATH	• *No specific subgroup identified*
US Department of Transportation (USDOT)	• Federal Highway Administration (FHWA) • Research and Innovative Technology Administration (RITA) • Federal Transit Administration (FTA) • Federal Railroad Administration (FRA)

9.1. CALTRANS

Caltrans mission is to provide a safe, sustainable, integrated and efficient transportation system to enhance California's economy and livability. To achieve this mission, the agency has laid out the following five goals:

- **Safety and Health:** Provide a safe transportation system for workers and users, and promote health through active transportation and reduced pollution in communities.
- **Stewardship and Efficiency:** Responsibly manage California's transportation-related assets.
- **Sustainability, Livability and Economy:** Make long-lasting, smart mobility decisions that improve the environment, support a vibrant economy, and build communities, not sprawl.
- **System Performance:** Utilize leadership, collaboration and strategic partnerships to develop an integrated transportation system that provides reliable and accessible mobility for travelers.
- **Organizational Excellence:** Be a national leader in delivering quality service through excellent employee performance, public communication, and accountability.

Caltrans's mission and objectives are executed across a network of 12 regional district offices and a central headquarters in Sacramento. The I-210 Pilot project involves participation from both the Caltrans Headquarters and the Caltrans District 7 offices.

9.1.1. CALTRANS DISTRICT 7

Caltrans District 7 is responsible for maintaining and operating state-controlled roads within Los Angeles and Ventura counties. Within the project corridor, this includes the I-210, I-605, I-10, SR-134, SR-110, and SR-57 freeways, as well as a few remaining sections of the SR-19 and SR-39 highways that have not been relinquished to Los Angeles County or local cities.

Traffic management equipment operated by the District in the I-210 corridor includes mainline, on-ramp and off-ramp traffic sensors; ramp and connector metering signals; changeable message signs; closed-circuit television cameras; and highway advisory radios. With a few exceptions, the District also operates and maintains traffic signals located at the intersections between freeway ramps and local arterials. Exceptions are for intersections with maintenance that has been delegated by agreement to a local jurisdiction, such as the Caltrans-owned signals along I-210 in Pasadena. In addition to the above field devices, the District operates a few park-and-ride facilities along the I-210 freeway, as well as the Los Angeles Regional Transportation Management Center in partnership with the CHP.

Caltrans District 7's involvement in the I-210 Pilot is primarily through its **Division of Operations**, which seeks to facilitate and optimize the movement of people, goods, and services in a safe and efficient manner. Within the division, project involvement is channeled through the following two offices:

- **Office of the District Traffic Manager** - Coordinates lane closure activities for construction, maintenance, and encroachment permit activities on the state highway system in a way that minimizes impacts on public traffic.
- **Office of Intelligent Transportation Systems –** Develops, integrates, implements, and manages various technology-based traffic management solutions.

Depending on project needs, one or more of the following divisions may also be involved:

- **Division of Planning** – Evaluates and identifies future improvement needs to the state transportation system.
- **Division of Maintenance** – Provides for the care and upkeep of state highways.
- **Division of External Affairs** – Provides customer service through communication, public outreach, and education, to build and enhance successful relationships in support of the Caltrans mission of improving mobility across California.

9.1.2. CALTRANS HEADQUARTERS

Caltrans Headquarters is responsible for setting general transportation policies, establishing statewide standards, and managing statewide programs. In addition to providing financial sponsorship for the project, the involvement of Caltrans Headquarters in the I-210 Pilot largely stems from a desire to explore how ICM systems similar to the prototype system that will be developed for the I-210 corridor could be deployed to other corridors within California.

Within Caltrans Headquarters, the **Division of Traffic Operations** is the primary entity involved in the I-210 Pilot. This division is generally tasked with addressing congestion, reliability, and safety issues associated with the operation of state highways. Within this division, involvement in the project is more specifically channeled through the following two offices:

- **Office of Strategic Development** – Develops and implements strategies and programs to address traffic issues within the state.
- **Advanced System Development Branch** – Oversees advanced and applied research initiatives, including pilot efforts, and program policy development and implementation associated with advanced transportation system management and operations and multi-modal traffic analysis.

Another participating entity is the **Division of Transportation Planning**, which is tasked with articulating a long-term vision for the development of California's transportation network and implementing statewide transportation policies through partnership with other state, regional, and local agencies.

Depending upon the specific needs of the project, the following divisions may also become involved:

- **Division of Maintenance** – Provides for the care and upkeep of state highways.
- **Division of Research, Innovation and System Information** – Division managing various research programs to research, develop, test, and evaluate innovative solutions that have the potential to improve the operation, maintenance, and management of the state's highway system.

9.2. LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY

The Los Angeles County Metropolitan Transportation Authority (Metro) is the state-chartered regional transportation planning agency and public transportation operating agency for the County of Los Angeles.

As a planning agency, Metro develops and oversees transportation plans, policies, funding programs, and both short-term (10 years) and long-range (20 to 30 years) solutions to address the county's mobility, accessibility and environmental needs.

As a transit system operator, Metro has the distinction of operating the third largest transit system in terms of annual ridership in the United States. This system is comprised of the following services:

- **Metro Bus** – Bus transit system operating local, rapid, and express buses on surface streets and some freeway segments, with a daily ridership of above 1 million boardings.
- **Metro Liner** – Bus rapid transit system featuring two service lines (Orange Line and Silver Line) operating on dedicated or shared-use busways with a combined daily ridership of over 43,600 passengers as of April 2014.
- **Metro Rail** – Mass transit system of two subway lines (Blue Line and Expo Line) and four light-rail lines (Gold Line, Green Line, Purple Line, and Red Line). This system features 87.8 miles of tracks and 80 stations, and had over 357,200 daily boardings on weekdays as of January 2014.

Additional transportation services supported by Metro within Los Angeles County include:

- **Metro Freeway Service Patrol** – Service operated in partnership with Caltrans and the CHP offering free quick-fix repairs and towing from freeways from a fleet of privately owned tow trucks instructed to patrol designated routes during peak commute hours.
- **Park-and-Ride Facilities** – Metro operates several park-and-ride facilities along the existing Gold Line. Several additional facilities that will eventually be operated by the agency are also currently under construction along the route of the Gold Line extension within the San Gabriel Valley. In addition to the Gold Line parking facilities, Metro also operates a few other park-and-ride facilities supporting Metrolink and other transit services throughout the corridor.
- **Local Bus Systems** – In addition to its own transit services, the agency partially fund 16 municipal bus operators.

- **Countywide Traffic Signal Synchronization Program** – Program providing financial support for local signal synchronization and arterial ITS projects, as well as LA County's traffic signal synchronization program. Typical projects involve upgrading traffic signals along a route to keep them synchronized, installing sensors to detect the presence of vehicles, coordinating the timing of the signals between successive intersections, and automatically adjusting the traffic signals to facilitate the movement of vehicles through the intersections.
- **Transportation project funding** – Oversees and distributes revenues from transportation sales tax measures (including Measure R and two prior measures) used to finance a wide array of transportation projects, such as bikeways, pedestrian facilities, and local roads improvements
- **RIITS Network** – Manages the RIITS regional data exchange network.

In addition to the above items, Metro supports a wide array of transportation projects within Los Angeles County, such as local road and highway improvements, bikeway development, and pedestrian facilities.

9.3. LOS ANGELES COUNTY

The **Los Angeles County Department of Public Works** (LACDPW) is responsible for road construction and maintenance, as well as the operation of traffic signals and Intelligent Transportation System devices, in areas under direct county administration. Within the I-210 corridor, this includes roads in the unincorporated areas of East Pasadena and East San Gabriel between Pasadena and Arcadia; the San Pasqual area between Pasadena and San Marino; and the Mayflower Village area between Arcadia, Monrovia, Duarte, and Irwindale. Some cities, such as El Monte, San Gabriel, and Temple City, contract with the county to operate the signals on their behalf. In such cases, the individual cities determine how each intersection should be controlled, but leave the day-to-day operation to the LACDPW. Over 425 signalized intersections across Los Angeles County are currently controlled by the agency from its TMC in Alhambra.

An ongoing LACDPW program supports the traffic management goals of the I-210 Pilot. This program, known as the Countywide Traffic Signal Synchronization Program, seeks to implement innovative, low-cost operational improvements to traffic signals on major streets throughout Los Angeles County. It is conducted with the technical and financial assistance of various cities, Caltrans, and Metro. Typical projects within the program involve upgrading traffic signal control equipment along a route to facilitate signal synchronization, installing sensors to detect the presence of vehicles on intersection approaches, and coordinating the operation of traffic signals across successive intersections.

In addition to roadway operations, the LACPW also operates four park-and-ride lots and five general aviation airports throughout the county, as well as both fixed-route shuttles and on-demand paratransit services in various areas of the county. The only park-and-ride lot close to the I-210 corridor is the Via Verde lot along I-10 near the SR-57 interchange. In addition to the above facilities and transit services, the department further administers various environmental programs and is responsible for issuing permits for activities to be conducted in the public roadway.

Another important transportation-related element operated by the department is the Information Exchange Network (IEN). This network was established to share traffic signal control information, and eventually traffic signal control itself, across the various county systems. As of June 2014, several agencies within the I-210 corridor were connected to this network, including the cities of Pasadena and Arcadia. A connection to RIITS, the traffic data information-sharing network used by Caltrans and Metro is also available. As part of the I-210 Pilot, plans are being considered to expand the data-sharing capabilities of the IEN and use it as a backbone data exchange system.

Additional county departments that may have an interest in the traffic management capabilities provided by the proposed I-210 Pilot include:

- **Los Angeles County Sheriff's Department** - Provides police services in unincorporated county areas, as well as within the cities of Duarte and Irwindale.
- **Los Angeles County Fire Department** – Provides fire and emergency response in unincorporated county areas, as well as within the cities of Duarte and Irwindale.
- **Los Angeles County Department of Coroner** – Conducts investigations into the cause of death for fatal accidents.

9.4. CITY OF PASADENA

Pasadena is a city of over 137,000 inhabitants located at the western end of the corridor. The city is known for hosting the annual Rose Bowl football game and Tournament of Roses Parade every January. It is also home to many scientific and cultural institutions, including the California Institute of Technology (Caltech), the Jet Propulsion Laboratory, the Art Center College of Design, the Pasadena Playhouse, the Norton Simon Museum of Art, and the Pacific Asia Museum.

Through its **Department of Transportation**, Pasadena currently maintains and operates over 300 traffic signals. In addition to ensuring the proper operation of traffic signals and supporting traffic sensing equipment, the department is responsible for periodically retiming the signals for normal operations and for handling special events. The department also manages several parking garages in the downtown Pasadena area, as well as on-street parking throughout the city. It is further responsible for the planning, implementation, and maintenance of bike lanes.

The **Transportation Planning and Development Division** of the Department of Transportation is responsible for project-specific and comprehensive planning activities. Comprehensive planning includes the development of citywide mobility plans, while project-specific planning activities include assessing transportation and traffic impacts due to development projects. The Division also leads the development of transportation-related information applications as part the Citywide GIS Program.

The **Transit Division** of the Department of Transportation is responsible for the planning and operations of the fixed-route **Pasadena Transit** system and the on-demand Dial-A-Ride service. Both services currently provide 1.2 million trips annually to Pasadena passengers using a fleet of 36 buses. The operations and management of both transit services are generally contracted out to a private fleet operator, with First Transit being the current contractor.

In addition to the Department of Transportation, the following departments may also have an interest in the traffic management capabilities of the I-210 Pilot:

- **Transportation Advisory Commission** – Advises the City Council on policies and important projects affecting the city transportation system.

- **Department of Public Works** – Maintains and enhances the city's infrastructure. This includes maintenance of traffic signals and other traffic control devices.
- **Pasadena Police Department**
- **Pasadena Fire Department**

9.5. CITY OF ARCADIA

Arcadia is a city of approximately 56,000 inhabitants located to the east of Pasadena. It is the site of the Santa Anita Park racetrack and home to the Los Angeles County Arboretum and Botanic Garden.

Through the **Engineering Division** of the **Development Services Department**, the city maintains 59 traffic signals on local arterials and streets. In addition to ensuring the proper operation of traffic signals and supporting traffic sensing equipment, this involves periodically retiming the signals for normal operations and for handling special events. The Engineering Division is also responsible for managing curb parking and city-operated parking lots, maintaining current traffic counts on arterial and collector streets, periodically assessing the adequacy of speed limits in collaboration with the city Police Department, and providing advice to the City Council on the establishment of truck routes.

In addition to the Engineering Division of the Development Services Department, the following city entities may also have an interest in the traffic management capabilities and traffic impacts that may be associated with the proposed I-210 Pilot:

- **Traffic Advisory Committee** - Representatives from various city departments charged with examining and solving problems related to traffic flow and safety, examining requests that may significantly impact traffic operations, and advising the City Council on transportation projects.
- **Transportation Division, Development Services Department** – Operates a general public on-demand bus transit service known as Arcadia Transit.
- **Public Works Services Department** – Responsible for maintaining all city-owned facilities, equipment, and infrastructure, as well as for the planning and implementation of projects included in the city's Capital Improvement Program.
- **Arcadia Police Department**
- **Arcadia Fire Department**

9.6. CITY OF MONROVIA

Monrovia is a city of approximately 37,000 inhabitants located to the east of Arcadia.

Through its **Department of Public Works**, the city is responsible for the management and operation of nearly 45 traffic signals, primarily along Foothill Boulevard, Huntington Drive, Duarte Road, Myrtle Avenue, and Mountain Avenue. In addition to ensuring the proper operation of traffic signals and supporting traffic sensing equipment, this involves periodically retiming the signals for normal operations.

In addition to the Department of Public Works, the following city entities may also have an interest in the traffic management capabilities and traffic impacts associated with the I-210 Pilot:

- **Traffic Safety Committee** - Serves as an advisory board to the City Council on traffic safety matters as established by the Municipal Code. Among its various tasks, this committee oversees speed limits, one-way streets and alleys, stop intersections, parking regulations, the parking citation process, public parking lots, truck routes, abandoned vehicles, bicycles, and wheeled toys.
- **Transportation Division, Community Development Department** – Operator of the city's general public dial-a-ride transit service known as Monrovia Transit.
- **Monrovia Police Department**
- **Monrovia Fire Department**

9.7. CITY OF DUARTE

Duarte is a city of approximately 21,000 inhabitants located to the east of Monrovia, near the I-210/I-605 interchange. This city only has 12 signalized intersections, mainly along its two main east-west routes, Huntington Drive to the north of I-210 and Duarte Road to the south. Maintenance of nine of these signals is the responsibility of the **Public Works Department**. Because of their location at the end of freeway ramps, the remaining three signals falls under the jurisdiction of Caltrans District 7.

In addition to the Public Works Department, the following entities may also have an interest in the management capabilities that may be provided by the I-210 Pilot ICM system and/or traffic impacts that may result from the use of this system:

- **Traffic Safety Commission** - Works on matters related to traffic laws, parking regulations, speed regulations, stop signs, traffic signals, traffic calming measures, pavement markings, warning signs, crosswalks and school crossings, traffic safety, and traffic engineering issues.
- **Transit Services, Department of Administrative Services** – Operates a three-line, fixed-route bus transit service known as Duarte Transit.

Duarte does not maintain city-based police and fire departments. Police services are provided by the **Los Angeles County Sheriff's Department**, while fire services are provided by the **Los Angeles County Fire Department.**

9.8. FOOTHILL TRANSIT

Foothill Transit is a joint powers authority of 21 member cities that was created in 1988 to provide fixed-route bus transit services in the San Gabriel and Pomona Valleys. Its 314-bus fleet provides bus service over an area of approximately 327 squares miles, carrying over 14 million passengers each year along 29 local and 6 express routes. Two of these routes are operated within the I-210 corridor, while three other routes are operated along the I-10 corridor. While only one bus route (the 690 Express) formally includes a section of I-210 as part of its scheduled route, the agency frequently uses the freeway to deadhead buses to specific locations.

Foothill Transit currently contracts out all of its service operations but maintains in-house management. The current operators are Veolia Transportation and First Transit. Veolia provides operations and maintenance for transit services originating from the agency's Arcadia Operations and Maintenance Facility, while First Transit is responsible for operations originating from the Pomona Operations and Maintenance Facility. Veolia is also responsible for managing its customer service and transit stores.

9.9. PRIVATE PARKING OPERATORS

Private parking operators include owners and operators of surface parking lots and parking garages within the I-210 corridor that are not operated by a transit agency, a city, Los Angeles County, or Caltrans. While not involved in the management of traffic on freeways and arterials, private parking operators may support the provision of parking spaces to help implement solutions enticing motorists to use transit or carpool services through specific agreements. In this capacity, they may collaborate with project stakeholders to help disseminate parking availability information to motorists and other travelers. This information may then help travelers find available parking and help parking operators fill underused parking facilities.

9.10. CALIFORNIA HIGHWAY PATROL (CHP)

The CHP has law enforcement jurisdiction over all California State Routes, U.S. Highways, and Interstate freeways, as well as over all public roads in unincorporated county areas. CHP officers are responsible for enforcing the provisions of the California Vehicle Code and for investigating and clearing car accidents, disabled vehicles, debris, and other impediments to the free flow of traffic. Since CHP officers are often the first responders at the scene of an accident or obstruction, they are often given the task of summoning paramedics, firefighters, tow truck drivers, or Caltrans personnel to help address the situation. After an incident has been resolved, they are further responsible for filing collision reports.

9.11. LA COUNTY SERVICE AUTHORITY FOR FREEWAY EMERGENCIES (LA SAFE)

The Los Angeles County Service Authority for Freeway Emergencies (LA SAFE) was formed in 1988 to help improve mobility and traffic in Los Angeles County by providing drivers the tools they need to travel safely and efficiently. To fulfill this goal, the Authority manages the following services:

- **Go511 Traveler Information System** – Free traveler information service providing traffic, transit and commuter service information via a toll-free phone number and website
- **Call Boxes** – Network of call boxes at key locations along major freeways enabling stranded motorists in need of assistance and without a cell phone to reach an assistance specialist.

9.12. SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS (SCAG)

Governed by a Regional Council of 86 local elected officials, the Southern California Association of Governments (SCAG) is a Joint Powers Authority and membership organization that was established to serve as the regional forum for the Counties of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura for cooperative decision-making by local government elected officials.

SCAG is designated under federal law as a Metropolitan Planning Organization (MPO) and under state law as both a Regional Transportation Planning Agency and a Council of Governments. It is the largest MPO in the nation. Key organizational responsibilities of the agency include:

- Maintenance of a continuous, comprehensive, and coordinated planning process resulting in the periodic development of a 20-year Regional Transportation Plan (RTP) and a 6-year Federal Transportation Improvement Program (FTIP). The RTP is a long-range blueprint that identifies projects and strategies to address the region's transportation challenges and improve transportation system performance, while the FTIP is the short-term programming document that identifies specific funding sources and amounts needed to implement the projects in the RTP.
- Development of a Sustainable Communities Strategy (SCS) to address greenhouse gas emissions
- Development of integrated land use, housing, employment, transportation programs and strategies for the South Coast Air Quality Management Plan
- Development of demographic projections
- Air quality planning for the Central Coast and Southeast Desert air basin districts
- Ensuring that the Regional Transportation Plan and the Federal Transportation Improvement Program conform to the purposes of the State Implementation Plans for specific transportation-related criteria pollutants, per the Clean Air Act
- Authorized regional agency for intergovernmental review of proposed programs for federal financial assistance and direct development activities
- Review of environmental impact reports for projects having regional significance to ensure they are in line with approved regional plans

To fulfill the above responsibilities, SCAG further develops, maintains and operates a regional travel demand model that is used to support various analyses. The council also maintains an active sub-regional modeling program that helps stakeholders develop, maintain, and apply sub-regional transportation models that are consistent with SCAG's Regional Model. Another supporting program also provides free Geographic Information Systems (GIS) services to SCAG member agencies.

Within the agency, the **Transportation Committee** is tasked with studying problems, programs, and other matters pertaining to regional issues of mobility, air quality, transportation control measures and communications, and making recommendations on such matters to the Regional Council. These activities are supported by four subcommittees respectively addressing active transportation, goods movement, high-speed rail, and transportation finance issues.

Staff from the **Planning & Program Department** further administers and implements various transportation-related programs and activities through the following two sub-departments:

- **Transportation Planning** – Develops and updates the RTP and FTIP; conducts long-range transportation planning to address corridor travel, goods movements, air travel, transit and passenger rail travel, transportation demand management, transportation system management, intelligent transportation systems, and transportation finance.
- **Land Use & Environmental Planning –** Addresses land use, housing, transportation, air quality, and environmental justice issues; and serves as technical and policy liaison with leading environmental groups, government/regulatory agencies, and elected officials.

9.13. SAN GABRIEL VALLEY COUNCIL OF GOVERNMENTS (SGVCOG)

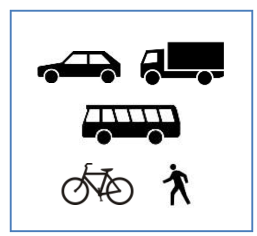
The San Gabriel Valley Council of Governments is a 35-member public agency comprised of 31 member cities, 3 Los Angeles County Supervisorial Districts (1, 4, and 5), and the San Gabriel Valley Water Districts. This agency was formed in 1994 as an umbrella agency to work on regional issues affecting communities of the San Gabriel Valley including transportation, housing, economic development, the environment, and water and to help forge a consensus in addressing issues affecting cities and communities within the valley. In addition to providing a regional forum, the agency plays an important role as a conduit between SCAG and the cities and counties of the region by participating and proving input on SCAG's planning activities.

San Gabriel Valley Council of Governments

Within the agency, the **Transportation Committee** studies problems, programs, and other matters pertaining to regional issues of mobility, air quality, transportation control measures. It also makes policy recommendations to the Governing Board on issues related to transportation. The committee is further supported by a **Transportation Technical Advisory Committee (TAC)** made up of City staff, County staff, and representatives from the COG's partner agencies that provides technical expertise on issues of importance for the Transportation Committee.

9.14. CORRIDOR TRAVELERS

One of the primary objectives of the proposed ICM system is to help travelers move efficiently across the I-210 corridor. In the context of the I-210 Pilot, travelers include the following subgroups:



- Private and commercial vehicle drivers
- Transit riders
- Bicyclists and pedestrians

9.14.1. DRIVERS OF PRIVATE AND COMMERCIAL VEHICLES

Vehicle drivers constitute the largest end-user group. This includes both drivers of private vehicles and truck/taxi drivers. Motorists will directly benefit from the implementation of traffic management strategies aiming to reduce delays and travel times along the I-210 freeway and corridor arterials. Motorists may also use disseminated travel information to better plan when they travel and which route they would take to reach a specific destination.

In addition to being information consumers, motorists can also be viewed as potential information generators. For instance, motorists who agree to have their movements tracked, within reasonable privacy limits, through GPS or cellular-based applications can effectively convert their vehicles into individual data collection systems enabling traffic management systems to collect valuable information about traffic speeds and trip patterns.

9.14.2. TRANSIT RIDERS

While transit riders represent a much smaller proportion of travelers, they constitute another important group of end users as transportation management strategies increasingly aim to promote transit system utilization. Similar to the motorists, transit riders can primarily be viewed as information consumers. However, they may also be viewed as potential information generators if they agree to use mobile applications enabling the capture of their travel movements.

9.14.3. PEDESTRIANS AND BICYCLISTS

Pedestrians and bicyclists traveling on the corridor arterials can be considered system stakeholders since their travel needs, and more particularly their safety, must be considered when assessing proposed changes to arterial operations. Similar to other travelers, these individuals may use disseminated travel information to better plan their travels within the corridor. While pedestrians and cyclists may not be significantly affected by changes in traffic conditions along corridor arterials, these changes may still affect their travel plans if they are planning to take a bus, catch a carpool ride, or take their car later.

9.15. COMMERCIAL FLEET OPERATORS

While commercial vehicles represent a relatively small fraction of the total number of trips made within the study corridor, these vehicles provide important support to the economic vitality of the region. Several fleet operators use the I-210 freeway to move goods within the northern section of the metropolitan Los Angeles area and beyond the region. Several warehouses are also located within the I-210 corridor. Both commercial vehicle operators and fleet managers would benefit from any improvement in traffic conditions within the corridor, as well as from the dissemination of improved travel information. Similar to motorists and transit riders, commercial vehicle operators may also be viewed as potential information providers, as many commercial vehicles are already equipped with automated vehicle location systems. If adequate agreements are in place, tapping into this information could convert these vehicles into probe vehicles used to collect information about roadway conditions and trip patterns.

9.16. TRAFFIC INFORMATION SERVICE PROVIDERS

Information service providers include all private entities disseminating travel-related information to travelers within the I-210 corridor. This includes radio and television station operators, and companies offering mobile navigation and travel information applications. Companies collecting probe vehicle data from fleets of commercial vehicles or fleets of application subscribers also fall in this category.

Within the Los Angeles area, television and radio stations play an active role in the dissemination of traffic information. Many television and radio newscasts use airborne reporters to obtain direct visual information about traffic conditions along given routes and to provide listeners with routing recommendations around congested areas. Providers of navigation applications also play an active role as a proportion of travelers may use the route recommendations provided by the applications to determine which routes or mode of travel they will take, or determine when to start a trip.

9.17. CONSULTING FIRMS AND EQUIPMENT VENDORS

Consulting firms may have a stake in the development of the proposed ICM system since the deployment of the system is likely to require interactions with systems that have been developed and/or implemented by these entities, either on the traffic and travel monitoring side or on the traffic control and information dissemination side. These interactions may impose limitations or constraints on what can be done, or require that some data or system operations conform to specific formats.

9.18. UNIVERSITY OF CALIFORNIA, BERKELEY – PATH PROGRAM

California Partners for Advanced Transportation Technology (PATH) is a research and development program of the University of California, Berkeley administered by the university's Institute of Transportation Studies with significant support from Caltrans. It is a multi-disciplinary program with staff, faculty, and students from universities worldwide and cooperative projects with private industry, state and local agencies, and nonprofit institutions. Its primary mission is to develop solutions addressing the challenges of California's surface transportation systems through advanced ideas and technologies, with a focus on the greater deployment of those solutions throughout California.

For the I-210 Pilot, PATH has been tasked by Caltrans with identifying and bringing together corridor stakeholders, developing the concept of operations and system requirements, developing general system operational rules, and formulating a road map for the cost-effective implementation of the I-210 Pilot. While PATH is expected to be significantly involved in the design and development of specific system components, such as the development of supporting simulation tools, it is not envisioned that PATH will develop all system components. In that respect, PATH's role will be to identify, engage, and manage appropriate vendors to support the development of a functional prototype ICM system.

9.19. U.S. DEPARTMENT OF TRANSPORTATION

The mission of the U.S. Department of Transportation (USDOT) is to develop and coordinate policies that will provide an efficient and economical national transportation system, with due regard for need, the environment, and the national defense. It is the primary agency in the federal government responsible for shaping and administering policies and programs to protect and enhance the safety, adequacy, and efficiency of the transportation system. In this capacity, the USDOT may play an advisory role in determining desirable features of the proposed ICM system for the I-210 corridor. Specific agencies of the department that may have an interest in the project include:

- **Federal Highway Administration (FHWA)** – Oversees the use of federal funds for constructing and maintaining the National Highway System (primarily Interstate Highways, U.S. Routes, and most State Routes). The FHWA also performs and sponsors research in the areas of roadway safety, congestion, highway materials and construction methods, and provides funding to local technical assistance program centers to disseminate research results to local highway agencies. The FHWA also publishes the Manual on Uniform Traffic Control Devices (MUTCD), which is used by most highway agencies in the United States to determine the size, color, and height of traffic signs, traffic signals, and road surface markings.
- **Research and Innovative Technology Administration (RITA)** – Advances transportation science, technology, and analysis, and improves the coordination of transportation research within the Department and throughout the transportation community. In recent years, this agency has been particularly active in the development, prototyping, and evaluation of ICM concepts, as well as the development of connected vehicle applications.
- **Intelligent Transportation Systems Joint Program Office (ITS JPO)** – Focuses on development of intelligent vehicles and intelligent infrastructure, and the creation of an intelligent transportation system through the integration of those components. This office has department-wide authority to coordinate ITS initiatives among various offices within the Department of Transportation.
- **Federal Transit Administration (FTA)** – Provides financial and technical assistance to regional and local transit agencies to develop new transit systems, as well as to improve, maintain, and operate existing systems. The FTA also oversees grants to state and local transit providers, primarily through its ten regional offices.
- **Federal Railroad Administration (FRA)** – Promulgates and enforces rail safety regulations, administers railroad assistance programs, conducts research and development in support of improved railroad safety and national rail transportation policy, and consolidates government support of rail transportation activities. The FRA also oversees distribution of funding to Amtrak and to the High Speed Rail initiatives currently under study in various states.

10. USER NEEDS

This section identifies key user needs governing the development of an eventual ICM system concept. These needs were determined based on a conceptual system analysis and inputs from corridor stakeholders and the ICM system development team. Elements presented in this section include:

- Categories of users
- User needs
- Corridor management strategies considered
- Managed roadway segments
- Data collection needs
- Asset requirements for system operations
- High-level operational needs
- Potential constraints to consider
- Compatibility with regional ITS architecture
- Institutional agreements
- Professional capabilities

10.1. CATEGORIES OF USERS

Table 10-1 identifies potential users of the proposed I-210 Pilot system. Two main categories of users are distinguished based on how individuals or agencies would interact with the system:

- **System operators (Direct users)** – Individuals actively participating in the operation of the system and having administrative access to some or all of its components.
- **End users (Indirect users)** – Individuals who do not actively participate in the operation of the system but who may use it to view how the corridor is operating or gather information that may help them make decisions.

Table 10-1 – Categories of System Users

System Operators (Direct Users)	End Users (Indirect Users)
• Traffic managers/Traffic engineers/TMC operators • Transit field supervisors • Transit dispatchers • Operators of participating parking facilities • Maintenance staff	• Transit vehicle drivers • Transit system managers • California Highway Patrol • Local police departments • Local fire departments • Metro Freeway Service Patrol • Parking facility operators not in system operations • Transportation system planners • Transportation supervisors • Transportation department directors • Agency/city executives and decision-makers • Public information officers • Information service providers • Commercial fleet operators/managers • Travelers

10.2. BASIC USER NEEDS

Table 10-2 describes the key user needs that will govern the development of the prototype ICM system for the I-210 corridor. These needs were identified following discussions with corridor stakeholders and a review of current operational processes. These needs will be the basis for the development of system and functional requirements at a later stage of the project.

Table 10-2 – System User Needs

ID	Title	Description
System Monitoring		
1	Collect and Process Multimodal Data Characterizing Corridor Operational Performance	The ICM system needs to collect, on a real-time or near real-time basis, data characterizing the operational performance of roadways, transit systems, parking facilities, and any other relevant transportation elements within the corridor being managed. This information will be used to identify whether incidents or events are having an impact on corridor operations and warrant the evaluation of alternate management strategies. Satisfying this need not only implies identifying which data to collect and collecting the data, but also determining how to validate and filter data from each potential source, as well as developing suitable processing algorithms to reliably derive the information sought.
2	Collect and Process Multimodal Corridor Travel Demand Data	The ICM system needs to collect data characterizing the demand for travel along the I-210 corridor. At the core of the system, this includes collecting data characterizing the movement of automobiles, buses, and trucks, as well as possibly individuals, along the freeways and key arterials in the corridor. Information about freight movement, as well as cyclists and pedestrian flows, should also be collected if deemed relevant to the corridor management effort.
3	Monitor Asset Availability	Agency operators need to monitor the status of all devices and facilities that may be used to control traffic, implement traffic management strategies, or disseminate information to the traveling public on a real-time basis. This means monitoring not only which devices are operational or down for maintenance, but also which operating devices may not be used because of operational constraints. It also includes monitoring available roadway capacity, available parking, and tracking the location of transit vehicle.
Decision Support		
4	Decision-making Assistance	The ICM system should indicate when an operational change is recommended, which systems/control devices should be modified to implement the desired change, and how these systems or devices should be modified. This includes considering both capacity and demand management strategies, where feasible.
5	Operational Forecast Capability	To assist with the selection of efficient corridor management plans, the ICM system needs to be able to forecast the effects of proposed actions, including a no action option, on traffic flow performance, transit system performance, and/or travel demand over near-term intervals.

Table 10-2 – System User Needs (cont'd)

ID	Title	Description
Decision Support (cont'd)		
6	Strategy Effectiveness Assessment	Before implementing a recommended strategy, system operators should be able to assess the potential impacts of the strategy on corridor operations. Similarly, following the implementation of an approved response strategy, systems operators must to be able to determine if the implemented strategy is having the intended effect. This implies identifying key performance metrics to use to conduct the assessments, developing processes to track changes in system performance over time, and providing suitable reporting capabilities. This also implies providing recommended courses of action based on the results of the strategy effectiveness assessment.
Control Capabilities		
7	Multi-Agency Coordination Support	Agencies participating in the I-210 Pilot system need to coordinate how they respond to incidents or events to avoid situations in which two agencies would implement incompatible local response strategies. This means establishing appropriate communication capabilities and a joint operational framework among participating agencies.
8	Automated Incident Response Capability	To the extent possible and allowed, the ICM system should have the capability to operate in a fully automated mode, without user intervention, during agreed-upon periods or when specific sets of circumstances are met.
9	Manual Control Capability	Under specific sets of circumstances, system users should have the ability to change one or more components of a response plan manually to address corridor operational issues not adequately captured by the ICM system. This includes an ability to alter traffic control directives and messages disseminated by information devices.
10	Preferred Control Setup Options	System users should have the capability to identify preferred control actions that the ICM system should consider first when developing responses to specific types of incidents or events. An example would be the ability to define, as a first response strategy, specific detours or traffic signal control plans.
11	Device Modification and Addition Capability	The system should allow authorized users to incorporate additional locations and devices into the control environment, as well as to modify or update existing control locations and/or devices.
12	Information Visualization	To facilitate decision-making activities, information characterizing system operations should be provided to system operators in a format that is easy to read and interpret, such as using maps, tables, color-coded displays, etc.
Information Dissemination		
13	Provision of Real-Time, Multi-Modal Information to System Operators	All authorized users should receive, to the extent of their availability, real-time data enabling them to manage their transportation network. This may include observed link speeds, estimated queue sizes, project flows, and various other metrics identified as relevant by individual system users. Providing this data implies not only operating a suitable information exchange network, but also managing restrictions on certain access, features, and/or system controls that may be imposed on certain data feeds. This also includes adding new information or data to the system on a regular basis, such as expanded transit service or the opening of new light-rail lines.

Table 10-2 – System User Needs (cont'd)

ID	Title	Description
Information Dissemination (cont'd)		
14	Provision of Real-Time, Multi-Modal Information to End Users	To help motorists, transit riders, and other travelers make informed decisions, particularly during incidents and events, the ICM system should provide real-time or near real-time information about travel conditions within the corridor to all corridor travelers. This can be done through existing 511 and roadside information systems, and/or the development of new mobile applications.
Data Management		
15	Historical Data Archiving	The data collected and information generated by the ICM system during its daily operations needs to be stored to support future offline analyses and corridor evaluations, as well as corridor modeling activities. Satisfying this need implies setting up one or more databases for storing historical data, determining the criteria governing which data will be stored and for how long, defining the protocols for archiving data, and defining the protocols for accessing and managing the database. Data output from the system should further be in a format consistent with the regional ITS architecture and be able to be utilized by other mainstream software systems.
System Management and Maintenance		
16	ICM System Management	Administrative functions need to be developed to enable authorized users to support the management of user accounts, system configurations, and system security.
17	System Maintenance	The ICM system should have the capability to provide system diagnostics and to alert relevant authorized users of any malfunctions or inoperable devices. Authorized users should be able to identify the specific devices needing maintenance, as well as the locations of these devices. The ICM system should also be able to perform self-diagnostic checks to assess maintenance needs and recommend maintenance actions.
18	Training Support	Adequate documentation must be available to support system operations and maintenance. Adequate training must also be provided when needed.

10.3. ICM STRATEGIES CONSIDERED BY I-210 PILOT

Discussions with corridor stakeholders have led to the identification of the corridor management strategies listed in Table 10-3 to be promoted as part of the I-210 Pilot. This table was derived from the set of potential ICM strategies that was presented in Table 8-3 in Section 8.4. For ease of reference, the identification numbers listed in Table 10-3 for each strategy corresponds to those assigned in Table 8-3.

It should be noted that the strategies listed in Table 10-3 do not necessarily represent all the travel management strategies that will be used within the I-210 corridor once the system is launched. Several of the strategies listed in Table 8-3 are already partially deployed or being independently deployed. For strategic or financial reasons, their deployment or expansion was not considered as being officially part of the I-210 Pilot. Strategies already in operation or being deployed include:

- **Provision of traffic-responsive or adaptive ramp metering (Strategy 4.3)** – Ramp meters along I-210 are already operating in a traffic-responsive mode. The Local Mainline Responsive (LMR) algorithm sets the metering rate on each on-ramp to a value proportional to traffic conditions observed on the freeway just upstream of the ramp. The ability to switch on the System-Wide Adaptive Ramp Metering (SWARM) algorithm also remains if so desired.
- **Provision of traffic responsive/traffic adaptive signal control along arterials (Strategy 4.9).** Several intersections along Fair Oaks Avenue in Pasadena are already controlled using a real-time signal control systems. A few intersections in Arcadia have also recently been equipped with an adaptive traffic signal control system. The primary objective of the I-1210 Pilot is not to implement additional adaptive or real-time functionalities at individual intersections but rather to explore how coordination of operations can be promoted across intersections and existing systems. This does not preclude local agencies to deploy new systems if they choose to do so.
- **Implementation of transit signal priority at signalized intersections (Strategy 5.1)** – Priority to transit vehicles is already provided at several intersections along Colorado Boulevard and Fair Oaks Avenue. An additional deployment is also currently under way along sections of Colorado Boulevard and Huntington Drive (see Figure 5-19).
- **Provision of signal preemption to emergency vehicles (Strategy 7.10)** – Many signalized intersections within the corridor are already equipped with devices enabling emergency vehicles to force the signal to return to green on the approach they are traveling.

Table 10-3 – Corridor Improvement Strategies Considered

ID	Strategy	Initial System	Future Add-ons
1.0	**Improving Transportation System Monitoring**		
1.1	Enable the operational status of control and informational devices to be monitored in real time	●	
1.2	Provide the ability to collect in real time traffic volumes measured by freeway and arterial sensors	●	
1.3	Provide the ability to collect in real time turning counts from intersections	●	
1.4	Provide the ability to measure in real time travel times between specific locations	●	
1.5	Enable traffic and travel demand monitoring systems to collect probe vehicle data	●	
1.6	Integrate real-time transit operational data into corridor monitoring system	●	
1.7	Integrate real-time parking operational data into corridor monitoring system		●
1.8	Integrate weather information into corridor monitoring system		●
1.9	Integrate traffic data available from third-party information service providers (e.g., INRIX, Navteq)	●	
1.10	Integrate user generated content that can be retrieved from third-party applications (e.g., Waze)	●	
2.0	**Improving Travel Demand Monitoring**		
2.1	Project near-future traffic flow demand by comparing real-time operational data to historical data	●	
2.2	Use probe data to assess routing/origin-destination flow patterns	●	
3.0	**Enhancing Information Dissemination**		
3.1	Establish data sharing capabilities among agencies operating within a corridor	●	
3.2	Establish a corridor data clearinghouse / data exchange	●	
3.3	Enable third-party information service providers to access relevant multi-modal operational data	●	
3.4	Provide real-time traffic data to traveler information systems	●	
3.5	Provide traffic and travel demand projections to travelers and information service providers	●	
3.6	Deploy changeable message signs along freeways	●	
3.7	Deploy dynamic route guidance system along arterials	●	
3.9	Expand 511 traveler information services	●	
3.10	Develop comprehensive web-based traveler information applications	●	
3.11	Develop mobile traveler information applications that can be accessed from mobile devices	●	
4.0	**Improving Traffic Operations**		
4.1	Develop a capability to evaluate near-future impacts of proposed corridor management strategies	●	
4.2	Develop a decision-support tool providing corridor managers with recommended courses of actions	●	
4.4	Coordinate ramp metering operations across adjacent freeway ramps	●	
4.5	Coordinate ramp metering operations with nearby arterial traffic signals	●	
4.7	Coordinate traffic signal operations across jurisdictions	●	
4.6	Develop specialized traffic signal control plans to deal with special events, specific types of incidents	●	
4.8	Implement traffic-responsive signal control (plan selection) along arterials	●	
4.22	Coordinate maintenance and construction activities across jurisdictions	●	●
5.0	**Increase Public Transportation Ridership**		
5.3	Adjust transit service frequency based on observed/projected travel demand and traffic conditions	●	
5.4	Promote coordination of transit schedules among agencies to facilitate transfers between various modes	●	
6.0	**Influencing Travel Demand**		
6.2	Recommend alternative routes around incidents / severe congestion	●	
6.3	Provide comparative travel time estimates for motorized travel along alternate routes	●	
6.4	Provide comparative travel time estimates for travel on alternate transportation modes	●	
6.6	Provide dynamic guidance to parking facilities with open spaces		●
6.9	Use of incentives to promote the use of alternate travel mode or changes in when a trip initiated		●
7.0	**Improving Response to Incidents**		
7.1	Enhance the capture of information characterizing incidents and describing response actions taken	●	
7.2	Develop joint, coordinated multi-agency incident response processes	●	
7.3	Provide alternate routing information on freeway changeable message signs	●	
7.4	Use dynamic trailblazer or changeable message signs along arterials to guide traffic back to the freeway	●	
7.6	Implement transit service route deviations around major incidents	●	
7.7	Implement additional transit services to alleviate the impacts of major incidents	●	
7.9	Implement signal timing plans maximizing throughput along congested detour routes	●	

10.4. MANAGED ROADWAY SECTIONS

Figure 10-1 identifies the key roadways that are to be managed by the ICM system that is to be implemented west of I-605 in the first phase of the project.

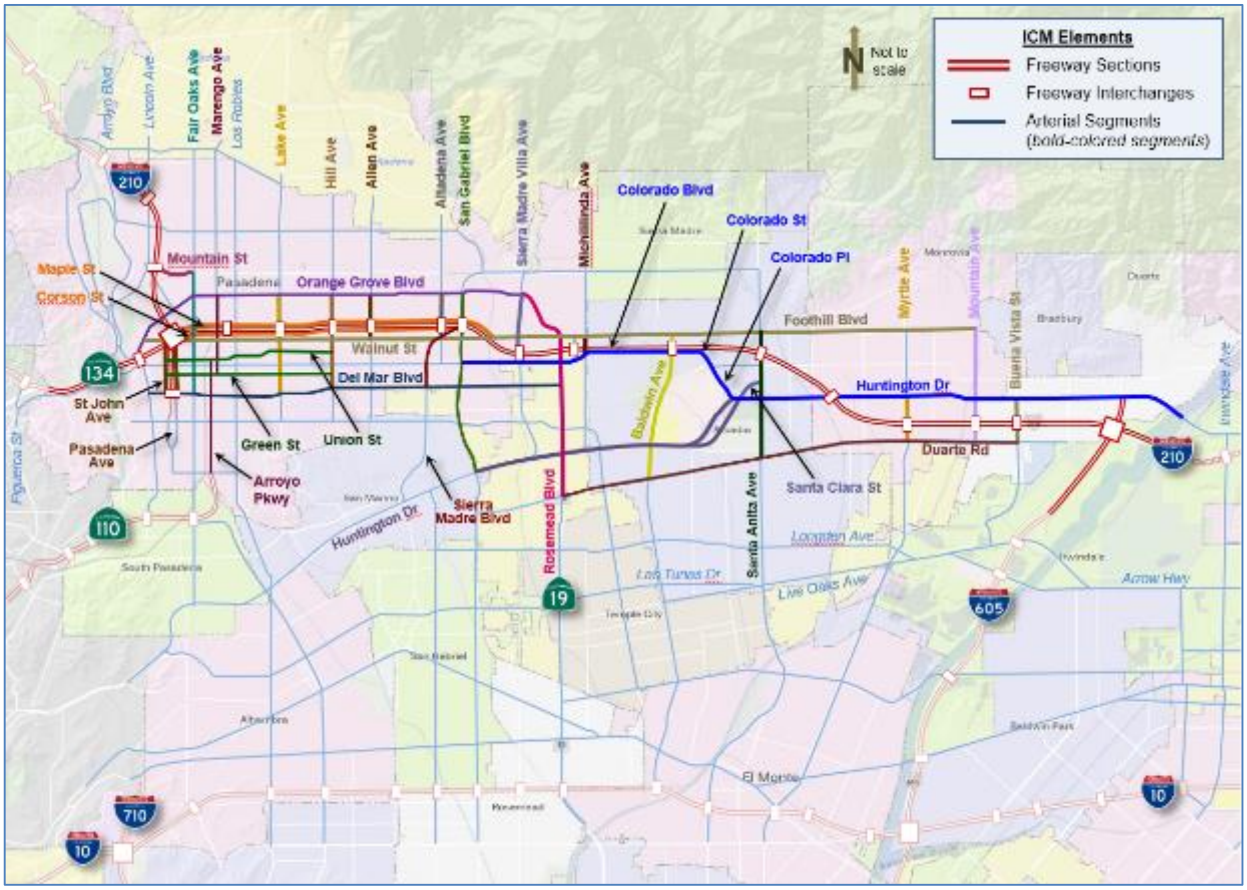


Figure 10-1 – Proposed ICM Roadway Segments

10.5. DATA COLLECTION NEEDS

In order to provide adequate system awareness and assessment of corridor operations, various types of data will need to be continuously collected by the ICM system. The following list identifies the types of data that have been identified as critical for supporting the operation of the proposed ICM system:

- **Characterization of traffic conditions on I-210 and other considered freeways:**
  - Traffic volumes, speeds and density on mainline and HOV traffic lanes
  - Traffic volumes on both on-ramps and off-ramps
  - Actual travel times along freeway segments
- **Characterization of traffic conditions on corridor arterials:**
  - Traffic volumes from key intersection approach
  - Proportion of vehicles turning left, going through and turning right at key intersections
  - Queue length estimates for key intersection approaches

  - Average traffic speed between intersections along arterials of interest
  - Actual travel times between intersections along arterials of interest

- **Characterization of parking availability**
  - Occupancy of park-and-ride facilities linked to the ICM system
- **Characterization of transit operations**
  - Frequency of passage of transit vehicles along relevant transit routes
  - Average occupancy of transit vehicles operating along each relevant transit routes
  - Active service deviations
- **Status of devices used to monitor traffic**
  - Health status of loop detectors, video detection systems, Bluetooth devices and any other types of monitoring devices used to collect traffic data
- **Status of traffic control devices**
  - Active metering rate at each freeway on-ramp
  - Signal timing plan in operation at each intersection
  - Health status of traffic signal control equipment
- **Status of informational devices**
  - Message currently displayed on freeway changeable message signs
  - Message currently displayed on arterial trailblazer signs or changeable message signs
  - Messages being pushed or recently provided to the regional 511 system and third-party information providers
  - Health status of freeway CMS
  - Health status of arterial CMS or trailblazer signs
- **ICM system status**
  - Information indicating whether the ICM system is currently idle
  - Health status of various ICM system components

Within the above list, information characterizing traffic conditions on freeway and arterial segments need be updated at least once every 15 minutes to ensure that current traffic conditions are truly being considered. Ideally, data characterizing traffic conditions should be updated at every 5 minutes to enable the ICM system to detect quickly changes in traffic conditions within the corridor. However, it is understood that the ability to poll data at such short intervals will depend on the specific data collection capabilities of the traffic flow monitoring systems that have been set up by each agency and that achieving short sampling intervals may not be possible everywhere.

Information characterizing the status of devices used to support ICM operations further needs to be available on an on-demand basis. For instance, information indicating which signal timing plan is currently being run at given intersections or which ramp metering rate is active on given freeway on-ramps must be available when the ICM system needs the information to assess corridor operations or develop response plans. In many cases, information availability is facilitated by the use of systems monitoring devices on a real-time basis, such as traffic signal control systems monitoring signal indications every second or compiling signal operational statistics on a cycle-by-cycle basis. Where such monitoring capability does not exist, appropriate remedial actions will need to be considered.

10.6. ASSET REQUIREMENTS

This section identifies the identified monitoring, control and informational assets that would support the successful deployment of a fully developed ICM system within the identified corridor.

- **Traffic monitoring**
    - Traffic detectors on freeway mainline, freeway on-ramps and off-ramps, freeway-to-freeway connectors, and at signalized intersections
    - Devices for measuring travel times between given locations
    - Probe vehicle data collection system
    - CCTV cameras
    - Incident detection system
    - Access to CHP/local law enforcement incident reporting systems
    - Access to systems used to report and manage roadway lane closures / events (for instance, Caltrans Lane Closure System)
    - Link to weather monitoring stations
    - Algorithms to assess traffic conditions (volume, speed, density, delays, etc.) on monitored roadway links
- **Transit monitoring**
    - Automated vehicle location systems
    - Passenger counting devices
    - Agency-based transit performance assessment system
- **Parking monitoring**
    - Operator-based parking monitoring system
- **Traffic control devices**
    - Freeway on-ramp and connector meters
    - Traffic signal controllers
    - Centralized traffic signal management systems
- **Traveler information systems**
    - Freeway changeable message signs
    - Arterial dynamic trailblazer signs or changeable message signs
    - Web-based traveler information system
    - Traveler information application for mobile devices
    - Communication link to regional 511 systems
    - Communication links to information systems operated by third-party providers
- **Data communication**
    - Communication links between TMCs and devices under TMC management
    - Communication network linking the various TMCs to the ICM server
    - Communication links with transit agency operations management system
    - Communication links with parking management systems
    - Communication links with external information systems

- **ICM System**
  - Data server
  - Simulation module
  - Decision support system

10.7. HIGH-LEVEL OPERATIONAL NEEDS

Various operational requirements were brought forward by corridor stakeholders during the development of the ConOps. The following is a summary of key high-level requirements that were identified as potential guides for the development of the proposed ICM system:

1. **Data gathering**
   - 1.1. The ICM system must be able to gather data from the various traffic detection systems in use within the corridor.
   - 1.2. The ICM system must be able to gather traffic signal operational data from the various traffic control systems in use within the corridor.
   - 1.3. The ICM system must be able to gather relevant transit operational data from participating local transit agencies.
   - 1.4. The ICM system must be able to gather relevant parking occupancy data from participating parking operators.
   - 1.5. The ICM system must be able to gather incident information from relevant sources.
   - 1.6. The ICM system must be able to gather information about planned event from relevant sources.
   - 1.7. The ICM system must be able to validate and assess the quality of the collected data.
   - 1.8. The ICM system must be able to validate the data it collects from sources from which a data quality check was not performed.
   - 1.9. The ICM system should archive in a dedicated database all the relevant data it gathers and generates.
2. **Assessment of corridor operations**
   - 2.1. The ICM system should evaluate corridor operations at regular intervals
   - 2.2. The ICM system should be able to derive various operational performance metrics from the data it gathers.
   - 2.3. The ICM system should have the capability of generating reports summarizing corridor operations.
   - 2.4. The ICM system should have the ability to detect whether unusual traffic conditions are observed within the corridor.
3. **Development of response plans**
   - 3.1. The ICM system should have the capability to initiate on its own the generation of response plans to address identified incidents or events.
   - 3.2. Unless specifically requested, the ICM system should not automatically develop response plans to address changes in traffic conditions caused by recurring traffic patterns.
   - 3.3. The ICM system should develop respond plans addressing changes in average traffic conditions, not changes associated with short-term, random traffic fluctuations.
   - 3.4. The ICM system should be able to develop and evaluate response plans within a window of less than 15 minutes.

4. **Implementation of response plans**
    4.1. The ICM system should be able to communicate recommended response plans to all relevant corridor operators.
    4.2. For the prototype system, Caltrans TMC staff will be responsible for implementing the recommended actions involving Caltrans-operated devices.
    4.3. Unless allowed by local agencies, the ICM system should not implement recommended control actions prior to obtaining approval for the action.

10.8. POTENTIAL CONSTRAINTS

In addition to the various needs outlined in previous sections, various operational policies and constraints may need to be considered in the development of the ICM system. The following are a few examples of institutional and technical constraints that may affect the development and implementation of the proposed ICM system:

- **Institutional constraints**
    - Due to liability issues, such as liability associated with injuries and deaths resulting from accidents occurring on diversion routes, jurisdictional policies may not allow recommendations of specific diversion routes to be communicated to travelers. For instance, existing policies may prevent the displaying of messages such as "Take Route N" in favor of more vague messages such as "Consider taking route N" or simply "Seek alternate routes".
    - Several local jurisdictions impose restrictions on the routes that truck traffic may take across their network. This may be due to various reasons, such as the desire, to reduce safety risks, noise in residential neighborhoods, pavement damages, etc.
    - Some jurisdictions may impose constraints on traffic signal operations during specific periods. As an example, based on safety concerns several cities along the I-15 ICM corridor in San Diego have expressed the desire to restrict the ability to send traffic on roads passing in front of elementary or middle schools around the times that school are scheduled to start and end.
    - Various regulations may govern the operation of changeable message signs. For instance, Caltrans often only allow pre-approved messages satisfying specific design guidelines to be displayed on freeway signs, which limit the ability of TMC operators to construct new messages on the go. In addition, while many of the Caltrans-operated CMSs have the capability of displaying messages alternating between two panes, operational policies may restrict message content to a single pane when traffic near the sign is moving at speeds above 35 mph to reduce driver traffic disruptions and safety risks (as in the case along the I-15 ICM corridor).
    - Strict regulations govern the design and installation of traffic signs and road markings. In California, these regulations are codified in the California edition of the Manual of Uniform Traffic Control Devices (MUTCD). Proper approvals may therefore be required for the installation of new traffic signs or new types of pavement markings supporting specific ICM applications.

  - Many agencies have established operational procedures defining what to do in specific situations. These established procedures may affect how various ICM strategies are developed and implemented. While modification to established procedures may be possible, the implementation of these modifications may require the development of justification documents and seeking approval from various involved agencies.
  - Different jurisdictions may have different requirements and regulations regarding the use of information technologies.

- **Technical constraints**
  - Inadequate traffic detection may exist at various locations within the corridor, creating a need to rely at some locations on estimates of traffic conditions rather than direct observations.
  - A variety of traffic signal control equipment with varying capabilities is in use within the corridor. For instance, both Type 170 and Type 2070 controllers are used to control traffic signals. For each controller type, various firmware is further used to implement the signal control functionalities. These variations result in a need to develop various interfaces to enable appropriate communications with the various pieces of equipment being used.
  - Various centralized traffic signal control systems are used throughout the corridor. This mix creates a control environment in which different systems process data and signal control requests in different ways.
  - Not all TMCs are staffed 24 hours a day, 7 days a weeks. The Caltrans TMC is the only one continuously staffed. Other TMCs are typically only staffed during peak travel periods. Across the TMCs, the operating hours during peak periods may also slightly vary.
  - Transit agencies may not have the necessary equipment to track vehicle occupancy and relevant operational metrics in real-time.
  - Park-and-ride facilities may not be equipped with the necessary equipment to track facility occupancy in real-time.
  - Suitable communication or control capabilities may not exist with all existing or desired field devices. The implementation of some traffic or demand management strategies may thus be dependent on the ability, or willingness, of participating agencies to perform the necessary equipment upgrades.

10.9. COMPATIBILITY WITH REGIONAL ITS ARCHITECTURE

Within California, Regional ITS Architectures have been developed for every major urban area. In each region, the defined architecture provides a blueprint for the coordination and integration of ITS applications used by various stakeholders in the transportation system. Each of the architectures is the result of a consensus among regional transportation stakeholders. The architectures typically outline the applications that are to be integrated, how the applications are expected to work together, and the information flows between them. Descriptions are further functionally oriented, not based on specific technology. They define what must be implemented, not how the specific functionalities must be implemented. This approach allows an architecture to remain relevant over time since the functions that a system must perform will often remain the same while technology evolves. New capabilities introduced by emerging technologies are typically address through periodic revisions of the defined architecture.

To facilitate interoperability among proposed ICM components, as well as with external applications, all proposed functionalities be compatible in principle with the 2004 Los Angeles County Regional ITS Architecture and Version 7.0 of the National ITS Architecture (released in January 2012). Such compatibility would not only promote interoperability among systems, but also facilitate information accessibility for system operators and system users. It would also ensure that all data elements exchanged between systems is defined in exactly the same way, and that there is a clear understanding of what each piece of information means.

A problem with assessing compatibility with the Los Angeles County Regional ITS Architecture is associated with the age of the architecture. Since its development in 2004, this architecture has not been updated. It therefore does not address many of the proposed functionalities that are expected to be part of the I-210 Pilot ICM system. The project will thus likely establish new architecture standards for the region based on the National ITS Architecture. It is expected that these new standards will ultimately be adopted and incorporated into the Los Angeles Regional ITS Architecture when it will next be updated.

10.10. INSTITUTIONAL AGREEMENTS

For corridors crossing multiple jurisdictional boundaries, inter-agency agreements is required to manage the system and coordinate responses to developing traffic congestion, incidents, and events in the most efficient manner. To the extent possible, ICM system development activities should take advantage of existing inter-agency cooperative agreements. However, due to the comprehensive nature of the proposed travel management approach and use of new approaches and technologies, it is highly likely that new institutional agreements will need to be developed or existing agreements may need to be amended to ensure the development and implementation of an effective ICM system satisfying the need and goals of all stakeholders.

The following are examples of interagency agreements that may need to be developed or amended as part of the project:

- **Project charter** – Document stating the scope, objectives, and participants in a project. Such document often serves as a reference of authority for the future of the project. Elements outlined typically include a preliminary delineation of roles and responsibilities, the project objectives, the main stakeholders, and the authority of the project manager.
- **Memorandum of understanding (MOU) –** Formal, but non-binding, agreement between two or more parties establishing as official partnership between them. These documents typically describe how the various parties would work together on a project or program.
- **Cooperative agreement** – Contracts between public agencies to provide services or facilities to one another.
- **Joint powers agreement (JPA)** – Legal agreement by which two or more agencies or jurisdictions agree to jointly implement programs, build facilities, or deliver specific services. Some agreements may also be used by an agency to lend its power to another agency.
- **Access and control of surveillance devices agreement** – Agreement defining the terms by which surveillance data, such as video images captured by CCTV or traffic detection system cameras,

could be accessed by individual agencies. The agreements may also define the ability of individual agencies to have the physical access and/or control the surveillance devices.

- **Data sharing agreement** – Agreements enabling participating agencies and/or entities to use data that has been collected and/or processed by other agencies.
- **Standard operation and maintenance procedures** – Agreements outlining the procedures that are to be followed by individual agencies in support of normal system operations. Such agreements may establish guidelines on how traffic signal coordination is to be promoted and implemented across jurisdictions, how freeway ramp metering rates are to be established, who would be responsible for the maintenance of ICM field devices, etc.
- **Incident and event management procedures** – Agreements outlining the procedures that should be followed by individual agencies in response to detected incidents and unplanned events. Such agreements may define procedures for identifying response routes for incident responders, identifying detours for the general traffic and transit vehicles, updating and disseminating incident-related traveler information, deploying and operating changeable message signs and trailblazer signs, initiating and terminating special traffic signal timing plans along arterials, and modifying freeway ramp metering operations.

10.11. PROFESSIONAL CAPABILITY NEEDS

In all of the areas discussed above, there is a need for trained and capable personnel to provide support for the installation and operation of the proposed ICM system. These capabilities can be divided into two categories:

- Capability needs for the initial installation and subsequent maintenance of the system
- Capability needs for the daily operations of the ICM system after its launch.

The first group includes professionals having skills in the selection of hardware to host the system and development software to operate system components. It also includes individuals having the necessary hardware and software skills to perform regular maintenance on the system and occasional system upgrades.

The second group includes professionals who will receive traffic management plans suggestions from the ICM System and who may be tasked with approving or rejecting control actions suggested by the system. This primarily includes individuals responsible for managing traffic within each jurisdiction within the corridor. It may also include transit fleet dispatchers. Individuals within this group should be able to understand quickly what is being suggested to them and have the ability to make quick and timely control decisions when necessary. To do so, they must have clear and concise ideas about how the corridor should operate at a given time of the day and be knowledgeable about the how freeways, arterials, and other relevant transportation systems within the corridor are typically operated. In particular, they must have the skills and/or experience to interpret how the performance metrics produced by the ICM system may translate into potential operational gains. Depending on their individual expertise, some of these individuals may need some basic training to inform them of the basic functions that other agencies perform, as well as to educate them on how traffic is typically managed across the various jurisdictions within the corridor.

11. SYSTEM OVERVIEW

This section presents an overview of the system to be developed. Elements described include:

- System goals and objectives
- General system capabilities
- Institutional framework
- Control framework
- Key system components
- Preliminary high-level system architecture
- Key system interfaces
- Standards to consider
- Modes of operations
- States of operations

11.1. SYSTEM GOALS AND OBJECTIVES

As was previously indicated in Sections 2.3 and 8.2, the primary goal of the proposed system is to improve travel mobility within the corridor during incidents and events. This translates into an end goal to improve overall system performance by increasing the efficiency with which existing systems are being used, through the implementation of cross-jurisdictional traffic and demand management strategies considering all relevant travel modes within a corridor. This translates into the following specific goals:

1. Improve operational situational awareness
2. Promote collaboration among corridor stakeholders
3. Improve incident response
4. Improve travel reliability
5. Improve overall corridor mobility
6. Empower travelers to make informed travel decisions
7. Facilitate multi-modal movements across the region
8. Promote transportation sustainability by reducing impacts on the environment
9. Improve corridor safety

For each of the above goals, Table 8-1 further identified the main operational objectives. Many of the objectives are similar to those of traditional transportation improvement projects. Many, however, also support a vision that operational and managerial gains can be achieved by implementing more comprehensive travel and system status monitoring systems, improved operational forecasting, improved information dissemination to travelers, enhanced data sharing capabilities, novel demand management approaches, and improved collaboration among transportation system operators.

11.2. SYSTEM CAPABILITIES

To help manage travel activities within the corridor during incidents and events, the proposed I-210 Pilot ICM system will have the ability to:

- Gather and archive information characterizing traffic operations, transit operations, and the operational status of relevant control devices within the I-210 corridor.
- Identify unusual travel conditions on the I-210 freeway or nearby arterials based on the monitoring of data provided by various traffic, transit, and travel monitoring systems.
- Identify situations in which an incident on transit facilities significantly affect travel conditions within the corridor.
- Provide corridor-wide operational evaluations to traffic managers, transit dispatchers and other relevant system managers, including projected assessments of near-future system operations under current and alternate control scenarios.
- Identify recommended detours around incidents or routes leading to the site of an event, considering observed travel conditions within the corridor. Depending on the need, and final system capabilities, specific detours may be recommended for motorists and transit vehicles.
- Identify recommended signal timing plan to be used at signalized intersections to improve and/or accommodate traffic flow influx during incidents and events, and improve overall corridor mobility.
- Identify recommended ramp metering rate to use on individual I-210 freeway on-ramps and connectors to maintain overall corridor mobility.
- Identify messages to post on available freeway and arterial CMSs to inform motorists of incidents and events.
- Provide guidance to motorists on the I-210 freeway and surrounding arterials using available freeway CMSs, arterial CMSs, and arterial dynamic trailblazer signs regarding which detour to take to go around an incident or which route to follow to reach the site of an event.
- Provide information to motorists about the availability of parking and transit services to help travelers make alternate mode choice decisions.
- Provide uniform traffic management strategies across jurisdictional boundaries during incidents and events.

11.3. INSTITUTIONAL FRAMEWORK

Figure 11-1 identifies the institutional framework supporting the operation of the I-210 Pilot ICM system. This framework identifies the following key groups of individuals:

- **Corridor Manager** – Individual tasked with assessing how the corridor is operating. For the I-210 corridor, it is expected that this individual will be a Caltrans staff. While this individual may have authority to approve/reject control changes affecting Caltrans-operated devices, this authority will not extend to the local agencies. Traffic managers from each agency are expected to retain decision authority over their respective systems. In this context, the Corridor Manager can be viewed as a system coordinator tasked with assessing how well the individual systems connected to the ICM system are operating together and determining whether specific issues need to be escalated for considering by the Technical Advisory and Management Committee, or Connected Corridors Steering Committee. Another important role will be to ensuring that agreed upon action items are carried through by the individual system stakeholders.

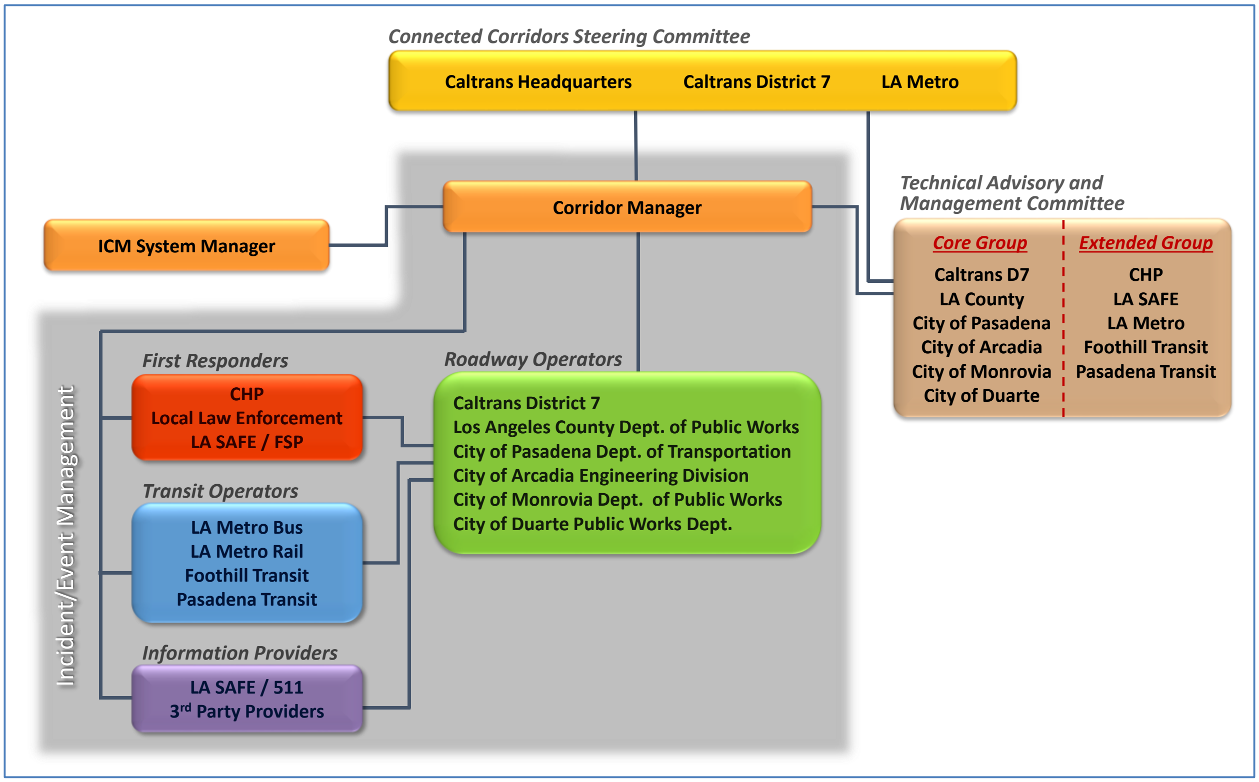


Figure 11-1 – Institutional Framework

- **Core System Operators** – Operators of the road network managed by the ICM system. These represent the individuals with whom will rest the decision to approve/reject traffic control recommendations made by the ICM system when automated control is not enabled.
- **Information Providers/Consumers** – Agencies and entities predominantly providing information to the ICM system or using information generated by it to affect their decision-making process. This includes first responding agencies, transit agencies, and information providers.
- **ICM System Manager** – Individual tasked with ensuring the good operation of the ICM system components. This includes managing needed system maintenance and repairs identified by him or brought to his attention by the Corridor Manager or other system stakeholders, as well as emergency repairs to address system breakdowns. Since the system servers are to be operated by Caltrans, the ICM System Manager will be a Caltrans District 7 employee. While he would be directly responsible for maintaining the ICM servers and Caltrans-operated devices, he would not be responsible for maintaining devices operated by other agencies. In this case, his only tasks would to follow-up on identified maintenance and repair activities that are to be conducted by local agencies, and to report on the status of these activities to the Corridor Manager.
- **Technical Advisory and Management Committee** – Committee composed of representatives from each of the agencies having a stake in the operation of the ICM system and tasked with addressing various issues with the operation of the systems that could not be resolved by the system operators and/or Corridor Manager. Roles assigned to this committee include reviewing and approving requests for changes in how the ICM system operations, advising on how to resolve operational issues affecting system operations, advising corridor stakeholders on how to resolve issues affecting multiple jurisdictions, assessing system performance against established

performance metrics, and identifying potential system improvements. The committee core group is to include a representative from each of agencies operating roadways within the corridor. Depending on the issues being considered, representative from the CHP, LA SAFE, Metro, and transit agencies are also expected to participate in the committee's activities.

- **Connected Corridors Steering Committee –** Committee composed of representatives of Caltrans District 7, Caltrans Headquarters and Metro tasked with addressing funding, legal, operational policy, and organizational issues associated with the operation of the I-210 ICM system, and well developing strategic vision and plans for future system enhancements and/or deployments.

11.4. CONTROL FRAMEWORK

Figure 11-2 illustrates the basic control framework of the proposed I-210 Pilot ICM system. The control framework involves the following key sequence of activities:

- **Data gathering** – Gathering of data characterizing travel conditions within the corridor from traffic flow sensors, automated vehicle location systems used to track buses and trains, onboard and roadside travel time monitoring devices, traffic signal control systems, etc.
- **Corridor operational evaluation** – Evaluation of travel conditions within the corridor, for both passenger car and transit travelers, based on the collected data and performance metrics of interest to system operators.
- **Response plan development** – Identification of traffic control changes, transit service adjustments, and information dissemination needs in response to incidents or events. This step potentially includes the development of both traffic and travel demand management strategies.
- **Response plan evaluation** – Utilization of analytical or simulation tools to assess the projected operational performance of the various response plan developed.
- **Response plan selection** – Selection of a recommended course of actions based on the results of the evaluations and performance thresholds agreed upon by system operators.
- **Recommended plan implementation** – Implementation of recommended control actions after a review and approval, if needed, by system operators.
- **Control loop** – Periodical re-evaluation of travel conditions within the corridor and, if necessary, generation of new response plans until the needs for ICM control disappears.

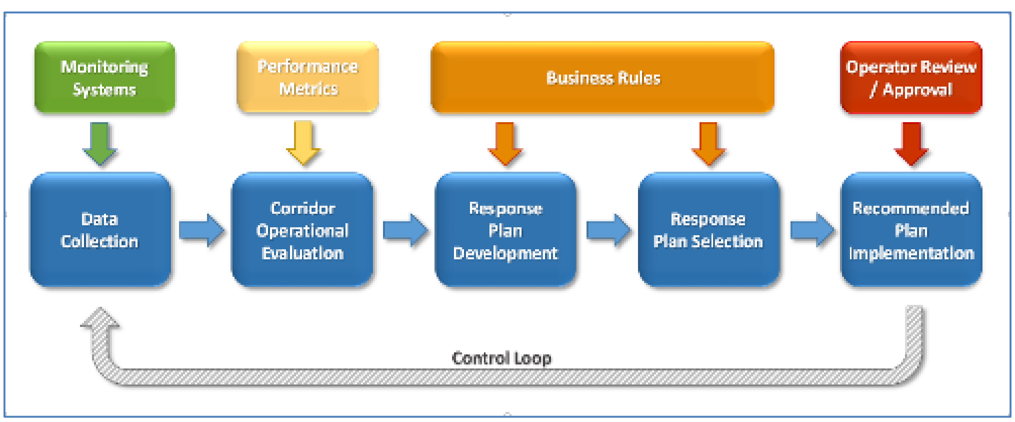


Figure 11-2 – I-210 Pilot ICM Incident/Event Response Control Framework

11.5. KEY SYSTEM COMPONENTS

This section identifies the key technical components of the proposed ICM system. This description applies to the diagram in Figure 11-3, which illustrates the how the various identified system components relate to others. Starting from the outer ring and gradually moving towards the center of the diagram, the following categories of components are defined:

- **Field control and informational elements** – Field elements are the foundational elements of the proposed system. These elements include devices to collect data from various systems contributing information to support ICM operations, as well as devices and services that can be used to affect traffic and travel behavior within the corridor. Key field elements supporting system operations include:
  - *Detectors* supplying information about traffic flows on roadway elements, such as loop detectors, video traffic detection systems, and travel time measurement devices.
  - *Onboard devices* that may be used to collect information about the movements of individual vehicles, including passenger cars, trucks, buses, and trains.
  - *Freeway on-ramp and connector metering signals* used to meter the flow of vehicles entering the I-210 or other freeways, as well as the flow of vehicles between freeways on metered connectors.

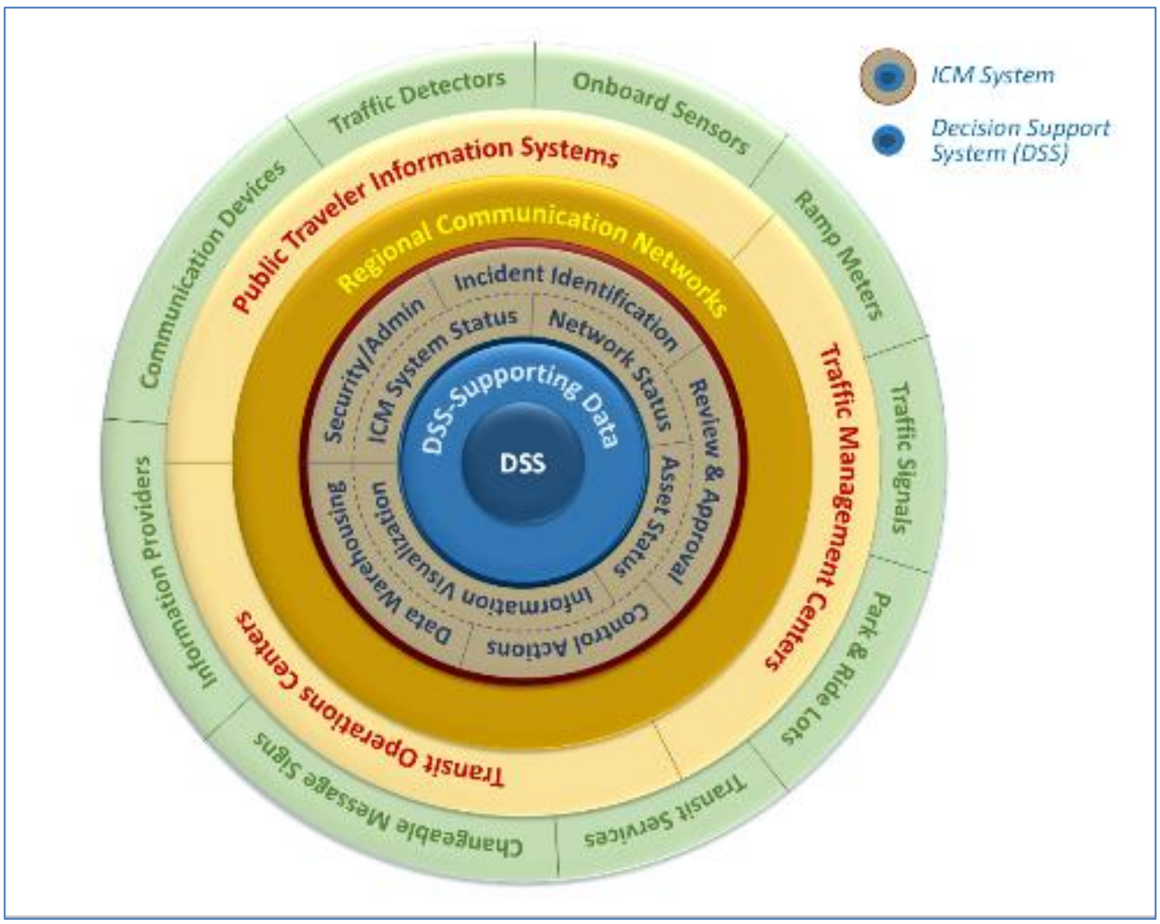


Figure 11-3 – I-210 Pilot ICM System Key Components

  - *Traffic signals* used to control traffic movements at intersections along arterials.
  - *Transit services* operated within the corridor, such as the Metro Gold Line and bus routes operated by Metro, Foothill Transit, Pasadena Transit, and other agencies.
  - *Park-and-ride lots* available to travelers within the corridor.
  - *Changeable message signs* installed along freeways and arterials used by the different roadway operators to inform motorists of travel conditions or provide route guidance.
  - *Communication equipment* used by transit dispatchers to contact bus or train drivers.
  - *Information services* provided by various third-party information service providers.

- **Management and operations centers** – Local decision centers providing connections between the ICM system and the various field elements. Key components within this category include:
  - *Traffic Management Center*s used by local and regional roadway operators to control the various devices under their jurisdiction and collect data generated by the monitoring systems they are operating. Centers considered include those operated by Caltrans District 7, the LA County Department of Public Works, the City of Pasadena, and the City of Arcadia. Also included here are the workstations providing the Cities of Monrovia and Duarte access to the centralized system controlling their traffic signals from the LA County Traffic Management Center.
  - *Transit operations centers* used by local transit agencies to manage the services they offer. This includes the centers operated by Metro to support their bus and rail operations, Foothill Transit, Pasadena Transit, and other transit agencies that may elect to participate in the project.
  - *Traveler information systems* operated by public agencies, such as the regional 511 traveler information system operated by LA Safe, Caltrans' Quickmap real-time traffic information system, or NextTrip information system operated by Metro.

- **Regional Communication networks** – Communication networks that may be used to circulate information between system components housed at different locations. The two key networks currently considered for supporting data exchanges within the I-210 corridor include:
  - *IEN* – Communication network developed by the Los Angeles County Department of Public Works to enable the sharing of traffic signal control information across the various systems used within the county.
  - *RIITS* – Communication network developed by Metro to enable real-time information exchange among freeway, traffic, transit, and emergency service agencies.

- **Technical ICM system elements** – System components directly operated by the ICM server and providing support to the various decision-making processes:
  - *ICM System Status* – Processes defining how ICM components are operating.
  - *Network Status* – Processes identifying the operational status of roadway segments, transit systems, etc.
  - *Asset Status* – Processes identifying the operational status and availability of traffic control and travel management assets.

  - *Information Visualization* – Methods enabling system users to visualize the collected data and the results of evaluations conducted by the ICM system.
  - *Security/Admin* – Processes used to control who has access to the system and to ensure the security of operations.
  - *Incident/Event Identification* – Processes used to identify incidents and events, and to characterize their impacts on network operations.
  - *Review & Approval* – Processes enabling stakeholders to review, if automated approval has not been enabled, the suggestions made by the DSS, make changes to the recommended actions, and ultimately approve/disapprove the recommended plans.
  - *Control Actions* – Processes converting an approved response plan into control commands to be transmitted to system assets and verifying that the requested changes have been implemented.
  - *Data Warehousing* – Database holding all relevant information collected by the ICM system to characterize corridor operations, as well as all information generated by the ICM system itself during corridor evaluations and the development of response plans to incidents and events.

- **Supporting data** – Information elements collected by the ICM system to support its decision-making activities. Key data elements to be collected include:
  - Data characterizing traffic flow demand and patterns.
  - Data characterizing the transit services being operating within the corridor.
  - Data characterizing the operational status of the various control and informational devices available for use.
  - Data characterizing the operational performance of buses and trains routes operated within the corridor, such as whether a vehicle is being delayed, when an arrival is expected at a particular location, etc.
  - Data characterizing various constraints that must be considered, such as school schedules, roadway closure timetables, etc.

- **Decision Support System** – Module implementing the intelligence of the ICM system. Key elements of this module include:
  - *Business rules* used to identify whether response plans should be developed to address active incidents or events, and to develop appropriate responses to the identified incidents or events.
  - *Simulation and analytical models* used to perform corridor performance assessments under current and possible future traffic, transit, and travel management strategies.

11.6. HIGH-LEVEL SYSTEM ARCHITECTURE

The diagram in Figure 11-4 presents a preliminary, high-level architecture of the proposed ICM system. It is not a design element, but rather a structure for describing the system operations. Design of the actual system architecture will be conducted in a later stage of the project. It illustrates how information is to flow between the various components of the system.

Core functionalities of the ICM system are at the center of the diagram. Communication between these functionalities and components operated by the various system operators is expected to be conducted using existing regional communication networks, in this case the IEN and RIITS networks described earlier. Surrounding the ICM systems are elements associated with one of the following five categories:

- **Roadway operators**, shown in blue
- **Transit operators**, shown in green
- **Law enforcement and first responders**, shown in red
- **Information providers**, shown in purple
- **Parking operators**, shown in dark gray
- **Other data suppliers**, shown in blue-green

For each illustrated entity, the direction of the arrow shows the direction of the exchange of information between it and the ICM system. Unidirectional arrows indicate entities only supplying information to the ICM system or only receiving data from it. Double-directional arrows indicate entities both supplying information to the ICM system and receiving information from it. Dotted lines indicate communication lines that do not currently exist but that are planned for the future.

Attached to each of the boxes representing a corridor entity are additional boxes showing the systems from which the ICM system it is expected to draw information and/or provide control recommendations.

Figure 11-4 – I-210 Pilot ICM Preliminary High-Level Architecture

11.7. KEY SYSTEM INTERFACES

This section summarizes the key interfaces that must be developed or verified to exist between the proposed I-210 ICM system and external elements to support the operations of the proposed system:

- **Interfaces with system operators**
  - Application enabling system administrators to manage ICM system operations and access to the system.
  - Application enabling roadway operators and transit dispatchers to input information into the system, visualize the results of corridor performance evaluations, review the control actions associated with developed response plans, and assess the status of implementation of a recommended response plan.
- **Interfaces to information collection systems**
  - Interface to PeMS, which is used by Caltrans as its main system for collecting, processing, and visualizing freeway flow data.
  - Interfaces to the traffic detection and traffic signal control systems operated by Caltrans (TransSuite), LA County (KITS), the cities of Pasadena (i2tms, QuicNet Pro, and SCATS), Arcadia (TransSuite), Duarte (KITS), and Monrovia (KITS).
  - Interface to the Bluetooth data collection systems operated by local agencies. Current systems include those operated by Pasadena and Arcadia.
  - Interfaces to transit operations management systems used by Metro Bus, Metro Rail, Foothill Transit, Pasadena Transit, and any other participating local transit agencies.
  - Interface to the Computer-Aided Dispatch (CAD) system used by the CHP.
  - Interfaces to dispatch systems used by local law enforcement agencies.
  - Interface to Caltrans' Lane Closure System (either direct interface or through PeMS).
  - Interfaces to parking management systems used by operators of park-and-ride facilities participating in the project.
- **Interfaces to communication networks**
  - Functions enabling the retrieval of data being circulated within the IEN network, and sending control commands to specific devices through the network.
  - Functions enabling the retrieval of data circulated within the RIITS network, and sending control commands to specific devices through the network.
- **Interfaces to device control systems**
  - Interfaces to traffic signal control systems operated by Caltrans (TransSuite), LA County (KITS), the cities of Pasadena (i2tms, QuicNet Pro, and SCATS), Arcadia (TransSuite), Duarte (KITS), and Monrovia (KITS).
  - Interface to Caltrans ATMS, which is used by Caltrans to control ramp meters on freeway on-ramps and connectors, as well as post messages on freeway CMSs. In this

case, because of the pilot nature of the project, no change can be made to the ATMS system. This means that Caltrans operators will be required to enter the recommended control actions manually into the system. This may include entering commands to change the ramp-metering rates, activating specific signal timing plans, selecting among a library of messages posted on CMS, etc.

  - Interface to systems used by local agencies to post messages on dynamic message signs operating along arterials.

- **Traveler information dissemination**
  - Application enabling law enforcement and first responders to access relevant information generated by the ICM system, such as recommended detour routes or information about current and projected congestion hotspots.
  - Application enabling the ICM system to feed relevant travel information to the regional 511 systems and/or applications operated by third-party information service providers.

11.8. STANDARDS TO CONSIDER

To facilitate communication and information exchanges between vehicles, devices, infrastructure, and applications, as well as interoperability among systems, relevant ITS standards should be considered when developing ICM applications. Beyond promoting interoperability, the application of ITS standards can provide significant additional benefits:

- **Avoiding premature obsolescence:** Purchasing equipment or developing applications conforming to standards that are recognized and supported ensures that the purchased equipment and deployed systems will remain useful and compatible with other devices well into the future.
- **Facilitation of coordination among operating agencies:** The adoption of common standards will ensure that operating agencies within a corridor can readily exchange information, and, in future vehicle-to-vehicle communication developments, that vehicles could easily interact with other vehicles and infrastructural elements independent of their location.
- **Reduced life-cycle costs:** Equipment maintenance represents a major component of life-cycle system costs. By ensuring that all equipment conforms to the same standards, agencies will be able to service ITS equipment without having to learn a different set of operating parameters for every piece of equipment of the same general type. It would reduce training and maintenance costs. In addition, parts and repair services can be sourced competitively rather than being limited to those available from the original equipment manufacturer.

Table 11-1 lists ITS standards that should be considered when developing system functionalities. The exact set of standards to be considered will depend on the specific functionalities being developed for the proposed ICM system and standards adopted within the Regional ITS Architecture.

Table 11-1 – Potential Relevant Standards

Author	Standard Title	Code
AASHTO / ITE / NEMA	Center-to-Center (C2C) Standards Group	NTCIP 1102-1104, 2104, 2202, 2303-2306, 2501-2502
	Center-to-Field (C2F) Standards Group	NTCIP 1101-1103, 2101-2104, 2201-2202, 2301-2303
	Communication between TCM and legacy field devices	NTCIP 1102, 1103, 2101-2103, 2301, 2302, TS 2-2013
	Global Object Definitions	NTCIP 1201
	Object Definitions for Actuated Traffic Signal Controller Units	NTCIP 1202
	Object Definitions for Dynamic Message Signs (DMS)	NTCIP 1203
	Environmental Sensor Station (ESS) Interface Standard	NTCIP 1204
	Object Definitions for Closed Circuit Television (CCTV) Camera Control	NTCIP 1205
	Object Definitions for Data Collection and Monitoring (DCM) Devices	NTCIP 1206
	Object Definitions for Ramp Meter Control (RMC) Units	NTCIP 1207
	Object Definitions for Closed Circuit Television (CCTV) Switching	NTCIP 1208
	Data Element Definitions for Transportation Sensor Systems (TSS)	NTCIP 1209
	Object Definitions for Signal System Masters	NTCIP 1210
	Objects for Signal Control and Prioritization (SCP)	NTCIP 1211
	Objects for Network Camera Operation	NTCIP 1212
	Object Definitions for Electrical and Lighting Management Systems (ELMS)	NTCIP 1213
	Object Definitions for Conflict Monitor Units (CMU)	NTCIP 1214
	Weather Report Message Set for ESS	NTCIP 1301
	Transit Communications Interface Profiles	NTCIP 1400
	TCIP Common Public Transportation (CPT) Objects	NTCIP 1401
	TCIP Incident Management (IM) Objects	NTCIP 1402
	TCIP Passenger Information (PI) Objects	NTCIP 1403
	TCIP Scheduling/Runcutting (SCH) Objects	NTCIP 1404
	TCIP Spatial Representation (SP) Objects	NTCIP 1405
	TCIP On-Board (OB) Objects	NTCIP 1406
	TCIP Control Center (CC) Objects	NTCIP 1407
	TCIP Fare Collection (FC) Business Area Objects	NTCIP 1408
	Communications protocols	NTCIP 2001, 2101-2104, 2201-2203
	Intelligent Transportation System (ITS) Standard Specification for Roadside Cabinets	ITS Cabinet v01.02.15
	Advanced Transportation Controller (ATC) Standard	ATC Standard v5.2b
	Advanced Transportation Controller (ATC) Model 2070 Standard	ATC 2070 v03.03
	Advanced Transportation Controller (ATC) Application Programming Interface (API) Standard	ATC API v02.06a
APTA	Transit Communications Interface Profiles (TCIP)	TCIP-S-001 3.0.4
ASTM	Dedicated Short Range Communication at 915 MHz Standards Group	E2158-01
	5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications	E2213-03
	Standard Guide for Archiving and Retrieving ITS-Generated Data	E2259-03
	Standard Practice for Metadata to Support Archived Data Management Systems	E2468-05
	Standard Specifications for Archiving ITS-Generated Traffic Monitoring Data	E2665-08
Caltrans	Assembly Bill 3418	AB3418E
IEEE	Standards for Incident Management Message Sets	1512, 1512.1, 1512.2, 1512.3, P1512.4
	Standard for Message Sets for Vehicle/Roadside Communications	1455
	Standard for the Interface Between the Rail Subsystem and the Highway Subsystem at a Highway Rail Intersection	1570
	Wireless Access in Vehicular Environments (WAVE)	802.11p, 1609
ITE	Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center to Center Communications	TMDD ver. 3.3
SAE	On-Board Land Vehicle Mayday Reporting Interface	J2313
	Dedicated Short Range Communications (DSRC) Message Set Dictionary	J2735
	Location Referencing Message Specification (LRMS)	J2266
	Message Set for Advanced Traveler Information System (ATIS)	J2354
	Standard for ATIS Message Sets Delivered Over Reduced Bandwidth Media	J2369
	Advanced Traveler Information Systems (ATIS) Family of Standards for Coding of Messages and Phrase Lists	J2540
ANSI	Commercial Vehicle Safety and Credentials Information Exchange	TS285
	Commercial Vehicle Credentials	TS286

11.9. MODES OF OPERATION

Depending on the desired level of involvement adopted by corridor stakeholders, the ICM system will be able to operate in one of the following three modes:

- **Automatic mode** – This mode will allow operations without interactions from transportation system operators. All control devices will be directly operated by the system based on information received from surveillance systems, external information systems, and predefined operational schedules. Response plans will be developed and implemented without user intervention. System users will only have the ability to review the decision made by consulting operational logs. This is the most difficult operational mode to configure, as the absence of user intervention provides little room for mistakes in the decision-making activities. This mode thus places the greatest responsibility for successful operations on the individuals tasked with configuring the decision-support system.
- **Semi-automatic mode –** This mode differs from the automated mode in the fact that it requires operator approval of all proposed transportation system management changes prior to their implementation by the system. The primary benefit associated with the introduction of operator approval is to add a level of user oversight on system operations. However, this mode of operation also introduces a risk for stalled operation if user approval cannot be obtained, either due to the unavailability of the responsible individuals or the continuous rejection of recommended actions by specific operators or stakeholders.
- **Manual mode** – This mode will require system operators to monitor corridor performance and determine by themselves an appropriate course of action to address identified situations. In essence, this operational mode provides decision support solely through the provision of greater situational awareness, i.e., solely through the provision to system operators by the ICM system of more information about current and projected system operations. It requires very little decision-support intelligence to used, as it assumes that all response plan development and decision-making activities are executed by system users.

For the first system deployment, the initial goal is to deploy a semi-automated system. This goal is in great part dictated by the pilot nature of the project. Since the project seeks to develop an experimental system, Caltrans has not authorized any resulting system to interface directly with the existing production systems. This means that TMC operators will have to implement actions recommended by the system for the Caltrans-operated devices. While a similar constraint does not exist for systems operated by local agencies, an approach similar to the one adopted for Caltrans may be followed for simplicity, unless an agency specifically requests experimentation with full automation.

Among the three modes described above, the automated mode is viewed as being ultimately the default mode of operation. However, this is also the most difficult mode to configure as it implies that the ICM system will be able to make correct management decisions on its own. This means developing a system capable of making rational decisions considering not only the results of quantitative operational analyzes but also the knowledge developed by years of operations. The need here is to develop a successful automated system that will allow system operators to devote more time on other pressing issues, thus requiring their attention only when truly necessary.

While the potential for operating in a fully automated mode at some times of the day is desired by some stakeholders, a semi-automated operation is viewed as being as important. For instance, semi-automated operation might be favored to help manage special events or unusual situations for which there may not be a clear response strategy or a need to consider factors not adequately modeled within by the ICM system.

11.10. STATES OF OPERATION

The proposed ICM system will provide decision support for a typical range of situations faced by transportation system operators. This includes the capability of developing recommended actions addressing the following operational situations:

- Non-recurrent congestion due to unplanned events, such as:
    - Unexpected road closures
    - Minor roadway incidents
    - Major roadway incidents
    - Transit accidents
    - Adverse weather events
- Non-recurrent congestion due to planned events, such as:
    - Maintenance and construction activities
    - Special events, such as concerts, sport activities
    - Forecasted weather events

While not providing recommended control actions, the proposed ICM system will keep monitoring and periodically evaluating travel conditions within the corridor during the following operational situations:

- Non-congested roadway operations
- Recurrent congestion

In addition to the ability to consider the operational situations described above, the ICM system will be robust enough to operate in a state of partial failure. Periodic system checks will further assess whether individual system components are operating as intended. These checks will also cover the health of input data feeds and quality of input data. Following the detection of an existing or potential problem, the system will inform the transportation system operators of the problem and try to continue its operation by compensating for the problem, to the extent that this may be possible. Should a major failure preventing adequate system operation be detected, the ICM system will then revert to a fail-safe operation focusing on the implementation of predetermined control strategies for the period of the day and day of week during which normal operation is suspended.

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12. OPERATIONAL ENVIRONMENT

This chapter describes the physical operational environment of the proposed I-210 Pilot ICM system. Elements described in this section include:

- Facilities
- Transportation systems
- Equipment
- Computing hardware
- Software
- Personnel
- Operating procedures

12.1. FACILITIES

The proposed I-210 ICM system is to be operated at various levels of functionalities from the following facilities:

- Caltrans' Los Angeles Regional Traffic Management Center (LARTMC)
- Arterial traffic management centers
- Transit operations centers
- First responders dispatch centers

12.1.1. FREEWAY TRAFFIC MANAGEMENT CENTER

The I-210 ICM system is to be centrally managed from physical or virtual computer servers operated from Caltrans' LARTMC in Glendale. As described in Section 5.1.1, this a facility jointly operated by Caltrans and the CHP, staffed 24 hours a day, seven days a week.

System components operated from the LARTMC are to support the following operations:

- Collection, processing, and archiving of traffic data from traffic and equipment monitoring systems operated by Caltrans on freeways and at State-controlled signalized intersections
- Monitoring the operation of freeway ramp and connector meters, traffic signals, changeable message signs, and control devices directly operated by Caltrans
- Processing and archiving of relevant traffic and control data sent to the ICM server by local traffic management centers
- Implementing control actions recommended by the ICM system on field devices operated by Caltrans
- Performing various other freeway and intersection control management activities

As was indicated in Section 11.7 (*Key System Interfaces*), because of the pilot nature of the project it is currently assumed that all control actions affecting Caltrans-operated devices will initially be manually entered into each management system by Caltrans operators, with possible automation after the system's demonstration phase.

12.1.2. ARTERIAL TRAFFIC MANAGEMENT CENTERS

Outside the LARTMC, access to key ICM functionalities is to be provided to each of the local jurisdictions operating traffic management devices along arterials within the study corridor. This includes implementing system components at the following locations:

- Los Angeles County Traffic Management Center (LACTMC) in Alhambra
- City of Pasadena Traffic Management Center in downtown Pasadena
- City of Arcadia Traffic Management Center in the city's administrative building complex
- Room within the Monrovia city offices where city staff can access the computer terminal giving them access to the city's KITS implementation on the LACTMC KITS servers
- Room within the Duarte city offices where city staff can access the computer terminal giving them access to the city's KITS implementation on the LACTMC KITS servers

At each location, the implementation of desired functionalities translates into a need to connect various data collection and control systems to the ICM servers operated from the LARTMC. City staff are further to be provided with a computer terminal enabling them to access the ICM system online and to perform specific functions from their location. System components to be installed at local traffic management centers are to support more specifically the following system operations:

- Collection and processing of data generated by the traffic monitoring systems operated by the agency
- Monitoring of the operation of traffic sensing, traffic signals, and informational devices operated by the agency
- Implementing control actions recommended by the ICM system on field devices operated by the agency
- Operating field devices from other jurisdictions for which they have authorization to do so
- Performing various other traffic management functions

Depending on final system design decisions, these control actions may be either manually entered into the respective management systems by local operators or automatically implemented by the ICM system. In particular, automated implementation may be considered to help with the management of incidents occurring during off-peak travel periods when local traffic management centers are not normally staffed.

12.1.3. TRANSIT OPERATIONS CENTERS

In addition to the traffic management centers, ICM system connections are to be provided to the following locations from which various transit services operating within the I-210 corridor are managed:

- Metro Bus Operations Control at the Metro Gateway building
- Metro's Rail Operations Control Center
- Pasadena Transit operations center
- Foothill Transit operations center

These ICM system connections will:

- Enable the ICM system to collect relevant transit operational data from the performance systems operated by the various agencies

- Enable transit dispatchers to obtain from the ICM system information about travel conditions within the corridor
- Enable transit dispatchers to enter manually into the ICM system, when relevant, information about enacted transit service changes that may affect the operation of the ICM system

12.1.4. FIRST-RESPONDERS DISPATCH CENTERS

Similar to transit dispatch centers, dispatch centers or offices used by law enforcement/first responder agencies are to be provided with a connection to the ICM system to support data collection activities. Locations that may be provided with such a connection, if desired by the respective agencies, include:

- CHP regional dispatch offices at the LARTMC
- Offices used by the police departments of the cities of Pasadena, Arcadia, Monrovia, and Duarte
- Dispatch center used by LA SAFE to manage the Metro Freeway Service Patrol

12.2. TRANSPORTATION SYSTEMS

Transportation systems under direct management from the ICM system include:

- **Freeways**
    - I-210 freeway, from the Arroyo Boulevard interchange north of Pasadena (Exit 22B) to the I-605 interchange in Duarte (Exit 36)
    - Section of SR-134 freeway between the Figueroa interchange and I-210 interchange
    - Section of SR-605 between Arrow Highway interchange and Foothill Boulevard
- **Arterials**
    - Arterials within the city of Pasadena, Arcadia, Duarte, and Monrovia shown in Figure 10-1

Additional transportation systems and facilities that may be affected or have their operations altered by travel management decisions made by the ICM system include:

- **Bus services**
    - Metro bus routes with sections within the I-210 corridor
    - Foothill transit bus routes with sections within the I-210 corridor
    - Pasadena Transit bus routes
    - CAD/AVL system used to monitor bus operations
- **Light-rail services**
    - Metro Gold Line
    - CAD/AVL system used to monitor light-rail operations
- **Park-and-ride facilities**
    - Park-and-ride facilities operated by Metro along the Metro Gold line and elsewhere within the I-210 corridor
    - Park-and-ride facilities operated by Caltrans along the I-210 freeway
    - Park-and-ride facilities operated by LA County within the I-210 corridor

As outlined in the scenarios of Section 14, it is assumed that the proposed ICM system will be developed to provide recommendations on the operations of traffic signals along selected corridor arterials and ramp metering signals on freeway on-ramps and connectors to help manage incidents and events. For the transit services, it is assumed that dispatchers from transit agencies receiving information from the ICM system will remain in charge of determining whether service changes are warranted, and what specific changes would be required, to address the identified situations. Finally, which parking occupancy information may be used by the ICM system to directly manage parking facilities within the corridor will not be developed at this time and will not be included in the scope of this ICM.

12.3. EQUIPMENT

This section describes the various equipment that will be used as part of the operation of the proposed ICM system. The following categories of equipment are described:

- Field devices
- Equipment within traffic and transit management centers

12.3.1. FIELD DEVICES

It is expected that the following field devices will be operated by the various jurisdictions participating in the I-210 Pilot in support of the proposed ICM system. Not all the listed devices will necessarily be new devices as many of the listed items are already being operated by the various agencies.

- **Caltrans District 7**
  - Freeway traffic detectors on mainline and HOV lanes, off-ramps, on-ramps, connectors
  - Traffic detectors on approaches to state-operated intersections
  - Ramp meters on freeway on-ramps and connectors
  - Signal control equipment at state-controlled intersections
  - Changeable message signs along I-210 and other relevant freeways
  - Travel time measurement devices installed along the I-210 freeway (if any are deployed)
  - CCTV cameras along the I-210, SR-34, and I-605 freeways

- **Los Angeles County Department of Public Works**
  - Traffic detectors on approaches to county-operated intersections
  - Signal control equipment at county-controlled intersections
  - Changeable message signs or other informational devices operated by the County on corridor arterials (if any are deployed)
  - Travel time measurement devices operated by the County on arterials (if any are deployed)

- **City of Pasadena**
  - Traffic detectors on approaches to city-operated intersections
  - Signal control equipment at city-controlled intersections
  - Bluetooth readers operated by the city
  - CCTV cameras operated by the city
  - Changeable message signs or other informational devices operated by the city on local arterials

- **City of Arcadia**
  - Traffic detectors on approaches to city-operated intersections
  - Signal control equipment at city-controlled intersections
  - Bluetooth readers operated by the city
  - CCTV cameras operated by the city
  - Changeable message signs or other informational devices operated by the city on local arterials (if any are deployed)

- **City of Monrovia**
  - Traffic detectors on approaches to city-operated intersections
  - Signal control equipment at city-controlled intersections
  - CCTV cameras operated by the city
  - Travel time measurement devices operated by the city (if any are deployed)
  - Changeable message signs or other informational devices operated by the city on local arterials (if any are deployed)

- **City of Duarte**
  - Traffic detectors on approaches to city-operated intersections
  - Signal control equipment at city-controlled intersections
  - Travel time measurement devices operated by the city (if any are deployed)
  - Changeable message signs or other informational devices operated by the city on local arterials (if any are deployed)

- **Metro Bus and Metro Rail**
  - CAD/AVL system to monitor bus operations
  - CAD/AVL system to monitor light-rail operations along the Gold Line

- **Foothill Transit**
  - CAD/AVL system to monitor bus operations

- **Pasadena Transit**
  - CAD/AVL system to monitor bus operations

12.3.2. EQUIPMENT WITHIN MANAGEMENT FACILITIES

The following devices are to be used within the traffic and transit management centers operated within the corridor to implement the proposed ICM system functionalities:

- **Caltrans Los Angeles Regional Traffic Management Center (LARTMC)**
  - ICM system servers described in Section 12.4
  - Computer monitor providing TMC operators access to the ICM system
  - Communication equipment enabling data collection from relevant Caltrans-operated management systems (ATMS, TransSuite, Lane Closure System, etc.)
  - Communication equipment enabling the ICM servers to be connected to the IEN, RIITS or other relevant external communication network

- **County/City arterial traffic management centers**
    - Web-connected computer enabling TMC operators to access the Caltrans-operated ICM system server
    - Communication equipment enabling local data collection and traffic management systems to push relevant information to the IEN, RIITS, or other relevant external communication network

- **Transit operations centers**
    - Web-connected computer enabling transit center operators to access the Caltrans-operated ICM system server
    - Communication equipment enabling the CAD/AVL systems operated by each transit agency to push relevant information to the IEN, RIITS, or other relevant external communication network

- **First-responders dispatch centers**
    - Web-connected computer or mobile devices enabling law enforcement officers to access the ICM system server

12.4. COMPUTING HARDWARE

The following servers will need to be set up within the LARTMC:

- **Data server(s)** – Servers tasked with collecting traffic and control data required for the operation of the ICM system from the various monitoring and control systems in operation within the corridor. These servers will also be tasked with collecting, validating, and pre-processing data that will be subsequently used by the Decision Support System, as well as with archiving any relevant data that may support later corridor evaluation and reporting needs.
- **Simulation Server(s)** – Servers implementing the ICM simulation capabilities. The number of servers to be used by the system will depend on how quickly a single server can execute a simulation with a high computational load and the maximum time allotted by the system to perform simulations.
- **ICM server** – Server implementing the functionalities of the of the Decision Support System
- **Test server** – Offline server to be used to test and refine new control rules or new system elements before implementing them into the active system
- **Backup server(s)** – Servers to be used if one of the main system servers fails

The technical details of each server will be determined at a later stage collaboratively with the corridor stakeholders during the development of system requirements.

It should be mentioned that the various servers listed above do not necessarily need to be physical machines. All of these can be virtual machines running in any secure location on the cloud. This would permit easy scalability and facilitate system portability.

In addition to the above computing hardware, the installation of new computers in the offices of local agencies may also be required to enable agency staff to access to the ICM server. This need will depend on the existing computing capabilities of each agency. If required, new computers would mostly be required to provide an online access to the system. In this context, relatively simple, off-the-shelf computers would suffice.

12.5. SOFTWARE

The I-210 Pilot ICM system will rely on various software elements to perform its operations. Key software elements are divided into the following main categories:

- ICM system applications
- Applications operating field devices
- External performance monitoring applications
- Regional traveler information systems
- Other third-party applications

12.5.1. ICM SYSTEM APPLICATIONS

The following key software modules are to be developed to provide the core functionalities of the proposed ICM system:

- **Data Manager** – Application tasked with collecting, validating, and pre-processing the data gathered from the various monitoring and control systems in use within the corridor. This application is also to be tasked with archiving both the collected data and operational evaluation data generated by the ICM system.
- **Incident/Event Manager –** Applications assessing whether an incident or event may be affecting corridor operations based on observed traffic patterns, incident notification messages received from external sources, or a database of scheduled events.
- **Asset Manager –** Functions determining whether an asset contained in the database can be used for the development of response plans or is unavailable because of operational constraints or other reasons.
- **Corridor Evaluation Module** – Application to be tasked with conducting corridor evaluations using simulation models or analytical tools.
- **Decision Support System** – Application tasked with determining when response plans should be developed, developing individual response plans, and selecting which plan should be recommended for implementation, if any.
- **Response Plan Implementer –** Processes used by system operators to review recommended plans, approve/reject a plan, and implement recommended plans if automated control is not enabled.
- **System Administration –** Functions to be used by system administrators to control who has access to the system and to what, as well as to configure general system operations.
- **Security Monitor –** Functions ensuring that only authorized users have access to the system.

12.5.2. FIELD DEVICE APPLICATIONS

During its operation, the ICM system will need to interact with various field devices, either through manual or automated interventions. Due to these interactions, the ICM system will need to understand how to communicate with each device to retrieve desired information and determine suitable control commands. This means understanding how various applications are used to manage and control the devices.

Table 12-1 – Field Device Applications

Field Device	**Agency**					
	Caltrans	**LA County**	**Pasadena**	**Arcadia**	**Monrovia**	**Duarte**
Loop traffic detectors	• Processed by traffic signal control system	• Processed by traffic signal control system	• Processed by traffic signal control system • SmartSignal (6 intersections)	• Processed by traffic signal control system	• Processed by traffic signal control system	• Processed by traffic signal control system
Video traffic detectors	• *(Future)* Processed by traffic signal control system	• Processed by traffic signal control system	• Processed by traffic signal control system	• Processed by traffic signal control system	• Processed by traffic signal control system (tbc)	• Processed by traffic signal control system
Bluetooth devices	• *None*	• *None*	• Digiwest BlueMac	• Iteris Vantage Velocity	• *None*	• *None*
Traffic signals (control system)	• TransCore TranSuite • Traffic Signal Management & Surveillance System (TSMSS)	• Kimley-Horn KITS	• Siemens I2tms • McCain QuicNet Pro • SCATS	• TransCore TransSuite	• Kimley-Horn KITS	• Kimley-Horn KITS
Ramp meters (control system)	• Caltrans ATMS	• *N/A*	• *N/A*	• *N/A*	• *N/A*	• *N/A*
Traffic signals (controllers)	• Caltrans C8V3 • Caltrans C8V4	• LACO-4E • LACO-1H • LACO-1HC • LCAO-1R	• LACO-4E • McCain 222P • McCain 233P • McCain 2033 • McCain 2033P	• LACO-4E • Fourth Dimension Traffic D4 • McCain Omni eX	• LACO-4E • LACO-3 • LACO-1R • LACO-1 • McCain 233E • McCain 200SA	• LACO-4E • LACO-1R
Loop traffic detectors	• Processed by traffic signal control system	• Processed by traffic signal control system	• Processed by traffic signal control system • SmartSignal (6 intersections)	• Processed by traffic signal control system	• Processed by traffic signal control system	• Processed by traffic signal control system
Changeable message signs	• Caltrans ATMS	• *None*	• McCain (4 signs) • Skyline (1 sign) • *(Future)* Daktronics	• *None*	• *None*	• *None*
Trailblazer signs	• *None*	• *None*	• *None*	• *None*	• *None*	• *None*
Closed Circuit Television	• Caltrans ATMS • *(Future)* Vehicle Classification System	• COHU camera *(1)*	• COHU cameras • Videowise Management Software	• PELCO analog and HD systems, with TransCore web application	• *2 cameras (tbc)*	• *None*
Data management	• PeMS	• *None*	• *None*	• *None*	• *None*	• *None*

Table 12-1 identifies the various software applications that may potentially interact with the ICM system throughout the corridor. Most of these applications are proprietary commercial software that is installed when devices are deployed.

12.5.3. EXTERNAL PERFORMANCE MONITORING APPLICATIONS

Data from various existing performance monitoring applications will be collected to support corridor operational evaluations performed by the ICM systems. Key existing systems expected to supply information include:

- **Caltrans' Performance Measurement System (PeMS)** – System used by Caltrans users to retrieve and analyze data from traffic detectors on freeway mainlines and ramps, lane closure reports posted on Caltrans' Lane Closure System, incident reports logged by the CHP, and accident records contained in the Traffic Accident Surveillance and Analysis System (TASAS).
- **Transit agencies' CAD/AVL systems** – Systems used by transit agencies to track vehicle locations and monitor route performance.

12.5.4. REGIONAL TRAVELER INFORMATION SYSTEMS

Web-based regional traveler information systems will be used to disseminate relevant information to corridor travelers. The primary system considered for this task is the Go511 application maintained by LA SAFE.

12.5.5. OTHER THIRD-PARTY APPLICATIONS

The I-210 Pilot ICM system will interface with several applications operated and maintained by external agencies or entities. By interfacing with these applications, the system will not only be able to provide operations managers more detailed information about corridor operations, but also facilitate information dissemination to travelers. Applications controlled by others that are considered in this ConOps include:

- Third-party traveler information systems
- Third-party navigation applications
- Third-party probe vehicle data collection systems

12.6. COMMUNICATION NETWORKS

In addition to the physical communication links, it is expected that communication between systems elements at various locations will be handled using the following existing networks:

- **IEN** (Information Exchange Network) – Communication network developed by the Los Angeles County Department of Public Works to enable the sharing of traffic signal control information across the various systems used within the county.
- **RIITS** (Regional Integration of Intelligent Transportation Systems) – Communication network developed by Metro to enable real-time information exchange among freeway, traffic, transit, and emergency service agencies.

As of January 2015, the following agencies have connections to the IEN:

- Los Angeles County Department of Public Works
- City of Pasadena
- City of Arcadia

The following agencies are further connected to RIITS:

- Caltrans Districts 7
- California Highway Patrol
- Metro bus and rail operations
- Foothill Transit

In addition, an interface between the IEN and RIITS already enables select data to be transferred from one system to another. This makes it possible to consider using both systems to support information exchanges across the various agencies involved in the operation of the I-210 Pilot ICM system. However, further investigations will be required to assess the extent to which each system supports the communication of all the desired data. If deficiencies are identified, corrective actions may involve changes to one or both systems. If incompatibilities persist, alternate solutions will need to be sought to support all the required data communication needs.

While individual agencies may have connections to the IEN and RIITS, an assessment will need to be made to determine to what extent individual systems from which data communication is required can actually use the communication networks. For instance, while LA County has an IEN connection, its KITS traffic signal control system has no interface enabling it to communication with the IEN. In another example, while Pasadena had developed interfaces enabling its i2tms traffic signal control system to communicate with the IEN, recent upgrades performed on the IEN or i2tms have caused the interface to stop working.

12.7. PERSONNEL

A variety of personnel will be used to operate the I-210 Pilot system. Key individuals to be involved in the operation of the ICM system include:

- ICM Corridor Manager
- ICM system manager
- Caltrans TMC Operators
- Caltrans Operations Division staff
- County/City traffic management staff
- Transit dispatchers
- First responders

12.7.1. ICM CORRIDOR MANAGER

The ICM Corridor Manager is tasked with assessing how the corridor is operating. For the I-210 corridor, it is expected that this individual will be a Caltrans TMC staff member. While this individual may have authority to approve/reject control changes affecting Caltrans-operated devices, this authority will not extend to the local agencies. Traffic managers from each agency are expected to retain decision authority over their respective systems. In this context, the Corridor Manager can be viewed as a system coordinator tasked with assessing how well the individual systems connected to the ICM system are operating together and with determining whether specific issues need to be escalated for consideration by the Technical Advisory and Management Committee, or Connected Corridors Steering Committee.

There will be no change to the experience or skill level required of the individuals assigned to the operation of the system. While some initial training will be needed to learn how to retrieve information from the system, enter information into it, and review/approve recommended control actions, no additional training requirement is currently expected.

12.7.2. ICM SYSTEM MANAGER

One or several Caltrans individuals from the LARTMC will be assigned the responsibility of overseeing the operation of the ICM system. This individual will be responsible for making any executive decisions regarding corridor operations that may result from complex situations and go beyond the simple acts of approving generated response plans and entering recommended control actions in the various systems operated by Caltrans. Due to the location of the ICM system servers within the LARTMC, this individual will also be responsible for assessing whether the ICM system components are operating normally and managing the resolution of technical operation problems that may arise.

Other than a requirement to learn basic elements of how the ICM system operates, there will be no change to the experience or skill level required of the individuals tasked with the management of the ICM system. While some initial training will be needed to learn how to retrieve information from the system, enter information into it, and review/approve recommended control actions, no additional training requirement is currently expected.

12.7.3. CALTRANS TMC OPERATORS

Caltrans TMC operators will be responsible for reviewing, approving, and implementing control actions affecting transportation management assets operated by Caltrans. The expectation is that these duties will be assigned to individuals normally staffing the TMC.

As indicated in Section 5.1.1, the LARTMC is staffed 24 hours a day, seven days a week. Throughout the day, the following individuals are normally on duty at the facility:

- **Regular shift (6:00 AM – 2:00 PM):** Two operators, one shift leader, two maintenance dispatchers, one dispatcher supervisor, and two CHP officers
- **Swing shift (2:00 PM – 10:00 PM):** Two operators, one shift leader, two maintenance dispatchers, and two CHP officers
- **Night shift (10:00 PM – 6:00 AM):** Two operators, one to two maintenance dispatchers, and one CHP officer

Within each shift, at least one person having operational knowledge of the ICM system and what to do when response plans are generated will be on duty (because of the pilot nature of the project, Caltrans operators are to enter the recommended control actions manually into the respective control systems at all times). This individual can be either one of the TMC operators or the shift leader.

There will be no change to the experience or skill level required of the individuals assigned to the operation of the system. While some initial training will be needed to learn how to retrieve information from the system, enter information into it, and review/approve recommended control actions, no additional training requirement is currently expected.

12.7.4. COUNTY/CITY TRAFFIC MANAGEMENT STAFF

Each local agency is expected to have on staff at least one person familiar with the operations of the ICM system. This person will be responsible for reviewing and approving the recommended response plans generated by the ICM system and, depending on the level of automation given to the ICM system, entering the recommended control actions into the various traffic management systems operated by the agency.

Within each agency, it is expected that the individual assigned to the operations of the ICM system will be the person normally tasked with the management of traffic within the jurisdiction. Since many jurisdictions do not typically staff a traffic management center 24 hours a day, seven days a week, a particular issue to be addressed during system design will be how to handle the implementation of ICM system recommendations issued when no one is on active duty. One option could be to enable automated approval of recommended control actions during off-duty periods, but only if an automated mechanism to implement the recommended changes in the operated systems is developed. Another option would be to develop a method for communicating with a specific person off-site who would have the authority to approve recommended changes and online access to the ICM system to enter the recommended control actions into the respective control systems.

There will be no change to the experience or skill level required of the individuals assigned to the operation of the system. While some initial training will be needed to learn how to retrieve information from the system, enter information into it, and review/approve recommended control actions, no additional training requirement is currently expected.

12.7.5. TRANSIT DISPATCHERS

Transit dispatchers from the participating transit agencies are expected to be primarily information consumers. It is anticipated that these individuals would mainly use the ICM system to help assess traffic conditions within the corridor and then determine based upon what they see whether existing transit services need to be altered. If service changes are implemented, they may also be required to provide to the ICM system information describing the changes made.

Based on the above assigned tasks, there will be no change to the experience or skill level required of the individuals assigned to the operation of the system. While some initial training will be needed to learn how to retrieve information from the system, enter information into it, and review/approve recommended control actions if needed, no additional training requirement is currently expected.

12.7.6. FIRST RESPONDERS

If desired, first responders may be provided some access to the ICM system. Similar to transit dispatchers, these individuals would primarily be information consumers. They would use the ICM system as a tool to help assess traffic conditions within the corridor, for instance to determine where traffic should be directed based on observed congestion hotspots and detours recommended by the ICM system. System access may also be used to facilitate the communication of incident information to the ICM system.

Based on the above assigned tasks, there will be no change to the experience of skill level required of the individuals assigned to the operation of the system. While some initial training will be needed to learn how to retrieve information from the system, enter information into it, and review/approve recommended control actions if needed, no additional other training requirement is currently expected.

12.8. OPERATIONAL PROCEDURES

Due to the nature of the system, the operating procedures have been detailed as part of the scenarios identified in Section 14.

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13. SUPPORT ENVIRONMENT

This section describes the planned physical support environment to maintain the deployed system. Supporting elements described in this section include:

- Facilities
- Utilities
- Equipment
- Computing hardware
- Software
- Communication infrastructure
- Personnel
- Operational procedures
- Maintenance procedures
- Cooperative agreements
- Outreach and Communications
- Equipment disposal

13.1. SUPPORTING FACILITIES

Each element of the I-210 ICM system is to be supported by the jurisdiction operating the device. It is assumed that support for the various devices can be accomplished within the existing facilities used by each jurisdiction (TMC, maintenance yards, etc.) and that no new additional facilities are thus required to support the system.

13.2. SUPPORTING UTILITIES

Operation of the proposed I-210 ICM system is facilitated by the use of existing infrastructures to supply power to the various system components that are to be deployed. It is assumed that power connections can be easily established with system components that are to be installed in the various TMCs. The only additional utilities needed are associated with the need to bring power connections to the following potential additional field devices:

- New CMSs along I-210
- New CMS or dynamic trailblazer signs along corridor arterials
- New traffic detectors at intersections

13.3. SUPPORTING EQUIPMENT

Excluding the purchase of computing equipment described in Section 13.4 the proposed I-210 ICM system does not require purchasing additional equipment by individual stakeholders to support its operations.

13.4. SUPPORTING COMPUTING HARDWARE

No additional computing hardware besides the equipment required for deploying the ICM servers described in Section 12.4, and only access for local agencies, is required to support system operations.

13.5. SUPPORTING SOFTWARE

The following software will be used to provide the associated supporting tasks to the I-210 ICM system:

- **System fault monitoring** – Computer software is required to monitor fault messages that may be sent out by individual field devices. While fault detection software is generally provided by vendors as part of the management application of a device, software may be needed within each TMC and on the ICM server to compile at a single location fault messages that may be coming from various sources.
- **System access monitoring –** Software to monitor who accesses the ICM system must be installed and operated to prevent unauthorized system use. In addition to disabling network access to the unauthorized user, the software should alert relevant system administrators of the event.

In addition to having the software perform the support tasks identified above, established processes are required to ensure that all the required software is available and up-to-date at each required device.

13.6. COMMUNICATION INFRASTRUCTURE

It is expected that all field elements contributing information to support ICM operations or that can be used to affect traffic and travel behavior will be connected to a traffic management or operations center. A communication network is further expected to enable the different centers to exchange information among themselves. Depending on the location, the communication capabilities may be provided by agency-owned or leased communication lines. Depending on the technology used, these communication lines may further consist of fiber optic cables, twisted pair cables, or wireless communication links.

Owners of the communication lines used by the ICM system are expected to provide maintenance support for the respective lines. This implies that:

- Agency-owned communication lines are to be maintained by agency personnel normally tasked with the maintenance of telecommunication equipment.
- Leased communication lines are to be maintained by the owner or the communication network according to the terms of the respective lease agreements.

Maintenance of the communication networks that may be used to connect the various traffic management and operations centers is to be provided by the agencies operating the communication networks used. This implies the following:

- Operation and maintenance of the IEN, if used by the ICM system, is to be provided by the Los Angeles County Department of Public Works.
- Operation and maintenance of the RIITS network is to be provided by Metro.

- If other communication networks are used instead of or in addition to the IEN and/or RIITS, the owner of the communication network used is expected to conduct its maintenance.

13.7. SUPPORT PERSONNEL

Support for the I-210 Pilot ICM system is to be provided by the various agencies operating field devices and equipment used by the system, as well as by the I-210 system developers and integrators until the end of their contractual obligations.

For each agency, support personnel needs will depend on the nature of the activities assigned to it. This section outlines the anticipated support personnel needs associated with the following groups:

- Connected Corridors Steering Committee
- Technical and Operations Advisory Committee
- Caltrans District 7
- Local jurisdictions
- Transit agencies
- First-responding agencies
- Software developers and system integrators

13.7.1. CONNECTED CORRIDORS STEERING COMMITTEE

The Connected Corridors Steering Committee will be responsible for addressing high-level issues regarding ICM system deployments. This committee is to be composed of representatives from:

- Caltrans Headquarters
- Caltrans District 7
- Metro

Key roles of the committee will be to address:

- Funding issues
- Legal issues regarding system operations
- Operational policy issues
- Organizational issues
- Strategic visioning and planning for future system enhancements and/or deployments

13.7.2. TECHNICAL AND OPERATIONS ADVISORY COMMITTEE

A technical advisory committee is to be set up to help corridor stakeholders address operational issues that may affect multiple jurisdictions. This committee is to be led by Caltrans District 7 and staffed with representatives from the various agencies operating elements of the I-210 Pilot ICM system. At a minimum, it is anticipated that at least one representative from each of the following agencies will participate in the committee's activities:

- Caltrans District 7
- Los Angeles County, Department of Public Works
- City of Pasadena, Department of Transportation

- City of Arcadia, Engineering Division
- City of Monrovia, Department of Public Works
- City of Duarte, Public Works Department

Depending on the issues discussed, representatives from the following agencies may also participate in the committee's activities:

- Metro Bus
- Metro Rail
- Foothill Transit
- Pasadena Transit
- LA SAFE

Roles assigned to the Technical and Operations Advisory Committee include:

- Reviewing and approving requests for changes in how the ICM system operates
- Advising on how to resolve operational issues affecting the ICM system
- Advising corridor stakeholders on how to resolve issues affecting multiple jurisdictions
- Assessing system performance against established performance metrics
- Identifying potential system improvements
- Addressing cross-jurisdictional operational funding issues

13.7.3. CALTRANS DISTRICT 7

As the lead agency for the development and operations of the I-210 Pilot system, Caltrans District 7 has supporting responsibilities not only for the maintenance of field devices and TMC equipment used by the ICM system, but also for the maintenance of the ICM system itself. This includes maintenance of the servers and software implementing the various functionalities of the system.

The key anticipated support personnel needs for Caltrans District 7 are:

- **Maintenance of supporting field devices and TMC equipment –** District 7 staff normally assigned to the maintenance of field and TMC equipment will be responsible for the maintenance of ICM system elements under Caltrans responsibility. These activities will likely be performed by staff from the Office of Intelligent Transportation Systems within the Division of Traffic Operations, as this Office currently has responsibility for supporting the various traffic management systems used by the District. These individuals are to inform identified Caltrans I-210 operators of any problem that may exist with the devices and equipment supporting the ICM operation. Conversely, system operators are to inform staff from the Division of Information Technology of any suspected operation, so that they could investigate the issue and resolve it.

- **ICM system maintenance** – While several aspects of the proposed I-210 Pilot ICM system are to operate in an automated mode, a Caltrans District 7 individual will be assigned the task of periodically reviewing system operations to ensure they are working as intended and that all previously identified maintenance issues with the system have been addressed.

- **Simulation model maintenance –** An individual familiar with the simulation model(s) to be used by the ICM system is required to perform periodic maintenance on them, in order to ensure that they remain an adequate representation of reality. Examples of tasks that may be assigned include changing coded lane markings, adding new roadways, or updating coded signal timing plans to reflect changes that were made to the actual road networks. This person would also periodically be tasked with reviewing and updating elements of the travel demand modeling not based on real-time data feeds. The system modeler may be either a Caltrans District 7 professional or a hired external consultant. In both cases, activities performed by the system modeler would be subject to review/approval by the Technical Advisory Committee.

In addition to providing maintenance support personnel from the Division of Operations at Caltrans, District 7 may initially have some advisory role in the operation of the system, particularly in the period following the system launch. These individuals may be required to participate in bi-weekly or monthly operational meetings for as long their presence is needed to address specific issues that could not be handled by the individuals normally assigned to the operation and maintenance of the system.

13.7.4. COUNTY/CITY AGENCIES

Local agencies will be responsible for providing support for their TMC environment and field devices. This includes support for traffic monitoring systems, traffic signal control systems, changeable message signs, computers, and any other technical equipment used to support the operation of the ICM system. Within each agency, ongoing support for system elements will be conducted by individuals normally assigned to the maintenance of field elements and information technology elements. Depending on the agency, this may be staff on city payroll or external individuals hired through contract support agreements to provide specific maintenance services.

13.7.5. TRANSIT AGENCIES

Similar to agencies managing traffic, transit agencies participating in the operation of the I-210 Pilot ICM system will be responsible for providing support for the operations of informational systems that may be used by the ICM system. This essentially includes support for the CAD/AVL systems already being used by each agency. In this context, it is expected that ongoing support for system elements will be conducted within each agency by the individuals normally assigned to the maintenance of the elements. Depending on the agency, this may be agency staff or external individuals hired through contract support agreements to provide specific maintenance services.

13.7.6. FIRST-RESPONDING AGENCIES

Staff normally responsible from the maintenance of computers and mobile equipment used by the CHP, local law enforcement agencies, and other first-responding agencies participating in the operation of the ICM system are expected to be responsible for maintaining the devices that may be used by agency staff for accessing the ICM system, if such access is desired. No other support personnel would be required from these agencies.

13.7.7. SOFTWARE DEVELOPERS / SYSTEM INTEGRATORS

Software developers responsible for the development of the I-210 ICM System will be required to support the application. If a fault occurs due to a software bug, these individuals will be required to resolve the fault. They will also be required to provide needed software updates, modifications, and changes, as per contractual requirements.

13.8. SUPPORTING OPERATIONAL PROCEDURES

Each agency will be responsible for developing and maintaining procedures for supporting the operation of the ICM elements under their responsibility. Depending on the nature of the work to be done, the procedures may involve activities within a single agency only or may define a set of coordinated activities across multiple agencies.

To ensure that corridor-wide management objectives are adequately addressed, members of the Technical Advisory Committee will be responsible for the oversight of these procedures and for assisting with the procedures coordination and management.

13.9. MAINTENANCE PROCEDURES

The maintenance of the I-210 Pilot ICM system is vital to its success. In order to work effectively, the system must be maintained. A maintenance program that includes routine preventive maintenance activities will need to be developed with appropriate staffing and annual budgets. Continual maintenance of system devices will ensure effective, optimal, and uninterrupted operation of the equipment.

Specific maintenance items described below in more detail include:

- General maintenance requirements
- Preventive maintenance needs
- Response to malfunctions
- System maintenance policies

13.9.1. GENERAL MAINTENANCE REQUIREMENTS

Each agency will be responsible for maintaining its own equipment based on an agreed-upon, unified, system-wide program with adequate funding. Agencies have expressed the need for a regional funding source or solution to ongoing maintenance costs, which will otherwise be a financial burden to local agencies. Maintenance programs and funding are an ongoing discussion among the stakeholders. At this time, they have not agreed on any solution.

13.9.2. PREVENTIVE MAINTENANCE NEEDS

Preventive maintenance activities are some of the most effective ways to reduce the overall life-cycle cost of the system while ensuring the devices operate in a reliable and optimal fashion. Common preventive maintenance activities include inspection, record keeping, cleaning, replacement, and testing. To be most effective, a well-planned maintenance program should be scheduled on a regular basis, taking into account proper resources (including both staff and equipment).

Procedures should be clearly defined and understood by all responsible parties, and all maintenance activities should be documented. Maintenance procedures should be stored in a central place to ensure that they can be appropriately used to monitor the performance of the system. This information is necessary to identify trends in maintenance needs and to plan and forecast maintenance requirements and expenses.

13.9.3. RESPONSE TO MALFUNCTIONS

The initial response to any reported malfunction of the system or a device is known as response maintenance. Response maintenance includes both field procedures used to restore device operation and shop procedures used to repair and test the malfunctioning equipment.

As an integral part of the response maintenance, procedures for reporting and scheduling repairs will need to be established. As part of these procedures, a standard prioritization process will need to be determined. This will require defining a hierarchical system of potential device malfunctions and the subsequent activities necessary to bring the device back into operation. Under conditions when inadequate resources are available to address all necessary maintenance activities, this hierarchical approach will establish which activities will be given priority. Special consideration will also need to be given to potential device and/or system malfunctions that create immediate safety issues for the public and agency staff.

Response procedures should be developed both for normal operating conditions and for situations with malfunctions occurring when maintenance staff is not readily available.

13.9.4. MAINTENANCE POLICIES

Each agency should develop policies for the maintenance of the devices they operate. The following are examples of basic maintenance policy elements that may be considered:

- Identify which preventive maintenance tasks should be conducted for each device. This includes a needs assessment/cost-effectiveness analysis. This will also require a review of activities prescribed by the device manufacturers.
- Determine whether systematic replacement or “replace as it malfunctions” better realizes the goals of the system, considering resource constraints.
- Determine whether vendor-provided support agreements are required to maintain the required uptime for each system.
- Develop specific guidelines for reporting non-scheduled maintenance needs and activities.
- Develop specific performance criteria for monitoring the performance of the maintenance management program.
- Develop clear procedures for each regularly conducted maintenance activity, including descriptions for both staff and equipment requirements.
- Establish a methodology for recording maintenance activities and identifying system maintenance needs.
- Develop criteria for prioritizing maintenance activities.

Since funding for maintenance may not necessarily be provided with the funds allocated for system development and deployment, each agency should also consider how they might potentially provide funding for the maintenance of specific system devices.

13.10. COOPERATIVE AGREEMENTS

Various cooperative agreements are required to support system operations. Key agreements include:

- **Traffic Signals/Ramp Meter Support and Update -** Establish guidelines, processes, and communication protocols between the agencies when changes to signal timing/operations and ramp meter rates are planned.
- **Planned Events and Update -** Establish guidelines, processes, and communication protocols when an agency is planning construction events, sports events, or other major events that will have traffic impacts along the mainline, and/or ramps, and/or arterials.

13.11. OUTREACH AND COMMUNICATIONS

Outreach and communications for the I-210 Pilot has been ongoing since mid-2011. Key stakeholders were identified early in the project and have already been engaged, resulting in individuals from each of the engaged agencies actively participating in meetings, document reviews, and numerous other outreach efforts. Key project stakeholders have further been holding weekly conference calls and bi-monthly in-person meetings to discuss various project-related items since early 2012.

Outreach and communication activities to support the I-210 Pilot ICM project were further defined in a plan that was prepared in 2013. These activities include:

- Building awareness of the I-210 Pilot for the consortium of stakeholders
- Providing information in multiple formats for a wide variety of audiences (stakeholders, elected officials, staff, public relations groups, the media)
- Keeping all stakeholders engaged, educated, and informed
- Generating support and positive media attention
- Providing timely, relevant information for general or specific purposes
- Building a strong community/corridor-oriented foundation of public support
- Building positive media coverage

. Planned future activities to further support the operation of the I-210 Pilot ICM system include:

- Development and maintenance of a dedicated I-210 corridor website
- Preparation and distribution of informational fliers
- Preparation of agreements to be signed by the project partners, such as a Project Charter and a Memorandum of Understanding
- Development of various marketing and communications strategies in coordination with various corridor stakeholders. This may include, among many other possibilities, preparing press releases and press events; developing newsletters, conference presentations, and various other publications and outreach materials; organizing videoconferences and webinars; and organizing social media campaigns.

13.12. EQUIPMENT DISPOSAL

There are no special requirements for the disposal of equipment included in the I-210 Pilot ICM project.

14. OPERATIONAL SCENARIOS

This section describes how the proposed system would operate in the following situations:

1. Non-event base operations
2. Moderate freeway incident
3. Major freeway incident
4. Major arterial Incident
5. Planned special events
6. Major transit incident

The objective in presenting these scenarios is to allow all stakeholders to identify clearly their expected role. Each scenario describes the steps that may be carried out by the system or its users in response to changing travel conditions. The examples are not meant to be all-inclusive but simply to show how the ICM system would operate, including:

- What may trigger a specific action
- Who or what would perform a specific action
- When communication may occur between the system, its users, and travelers
- What information may be being communicated

Two diagrams are used to illustrate each scenario. The first diagram provides a geographical view of the transportation elements involved. Figure 14-1 defines the various elements illustrated in each diagram, while Figure 14-2 in the section presents a first example of a completed diagram. The second diagram shows how the various actions in the scenario translate into information flows between key system elements. Figure 14-3 in the next section presents a first example of such a diagram.

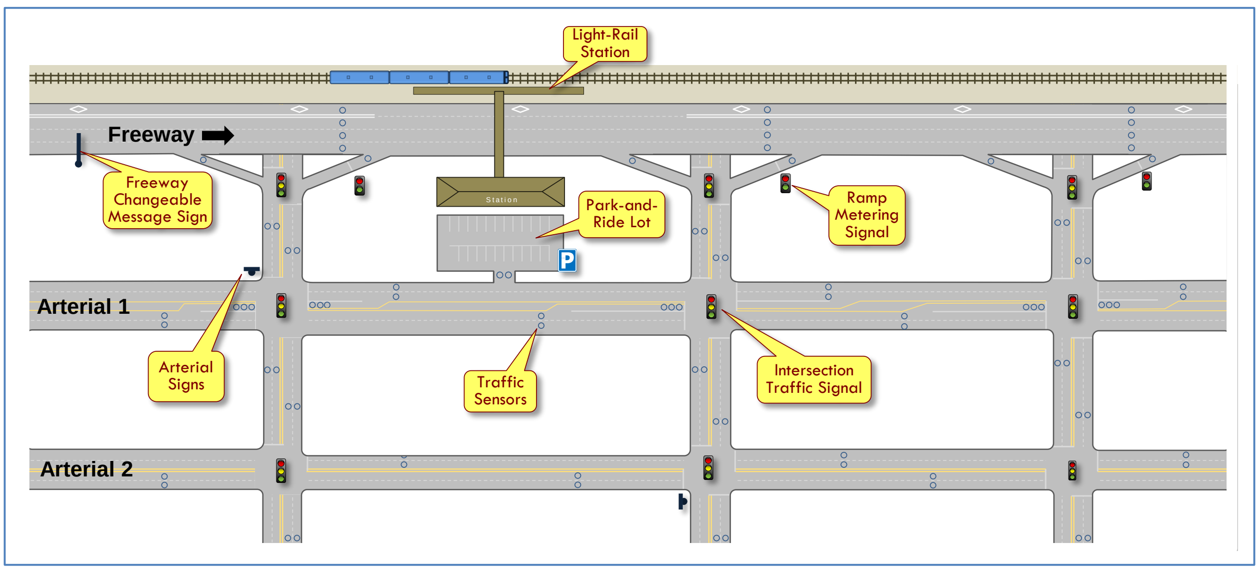

Figure 14-1 – Operational Scenario Template Diagram

NOTE: In each scenario, time intervals are mentioned for illustrative purposes only. During For instance, the scenarios indicate that data is to be polled from monitoring systems every 5 minutes, and that corridor evaluations are to be executed every 15 minutes. The actual duration of the intervals to be used will be determined during the development of the system requirements.

14.1. SCENARIO 1 – NO-INCIDENT/NO-EVENT OPERATIONS

In the absence of incidents or planned events, system activities will be limited to collecting and analyzing data to assess travel conditions in the corridor. These evaluations would be conducted every few minutes should unusual traffic flow patterns be observed at the end of an evaluation, warning messages would then be sent to the relevant system users to inform them of the situation. Warning messages would keep being generated at each evaluation until the situation disappears or an input is made into the system to identify formally the situation as an incident. If the latter occurs, the system would then operate as described in the incident management scenarios later in this section.

The system could also be used during normal travel conditions to produce periodic reports on corridor performance. Depending on user preferences, these reports could be generated for every hour, a given interval, or on a daily, weekly, or monthly basis. Reports could include:

- Identification of intersections with limited spare capacity
- Identification of freeway ramps affected by queue spillbacks
- Traffic performance along given routes in terms of average travel time, incurred delay, and travel time reliability

A specific timeline of actions associated with the operation of the proposed ICM system during normal-day operations is as illustrated in Figure 14-2 and Figure 14-3, and described in detail below. Numbers in both figures refer to the number associated with each paragraph in the list below.

1. **Tracking of travel conditions within corridor** – Throughout the day, the ICM system polls data every 5 minutes from various monitoring systems to update its operational view of the corridor. Collected data could include:
    a. Traffic flow data from mainline freeway sensors
    b. Traffic flow data from freeway on- and off-ramps
    c. Traffic flow data from arterial sensors
    d. Probe vehicle data from various suppliers, to track travel times or speed profiles along specific routes, as well as to assess potential changes in routing patterns
    e. Incident reports from CHP and local law enforcement and first responding agencies
    f. Operational data from transit agencies, such as significant schedule delays, route deviations
    g. Parking occupancy data, where available, to assess parking opportunities
2. **Periodical corridor operational assessment** – Every 15 minutes, the DSS predicts how traffic conditions will evolve over the next hour if the observed traffic demand patterns are maintained and if all active and projected traffic management strategies are maintained. If an unusual situation is detected, the situation is flagged and brought to the attention of the relevant traffic managers. If it is determined that the situation is the result of an incident, the ICM system then switch to an incident management mode and operate as described in one of the scenarios described below. If not, the evaluation results are then saved for potential use in later evaluations or to support the generation of operational reports.

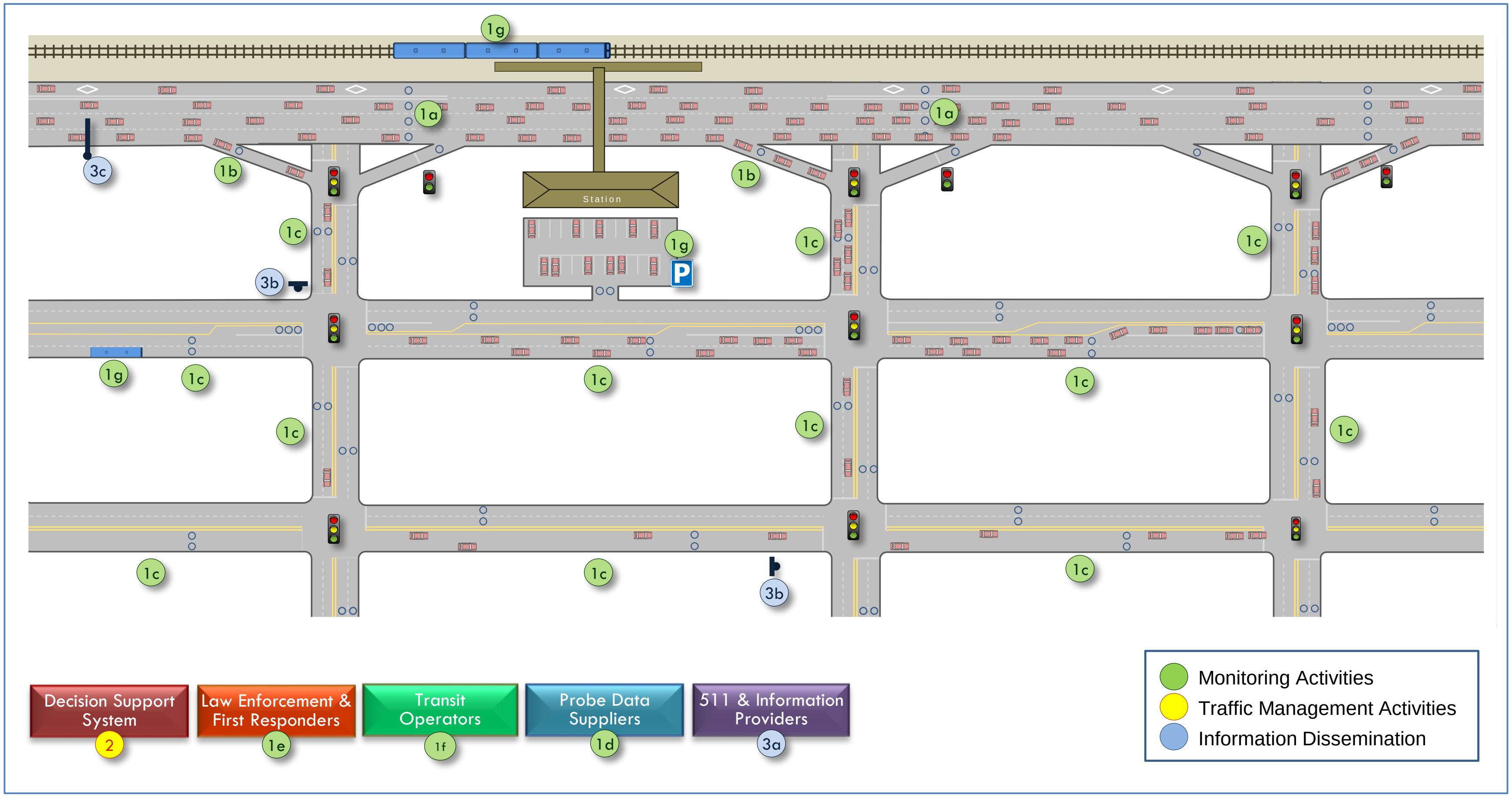

Figure 14-2 – No-Incident/No-Event Operation: Active Elements

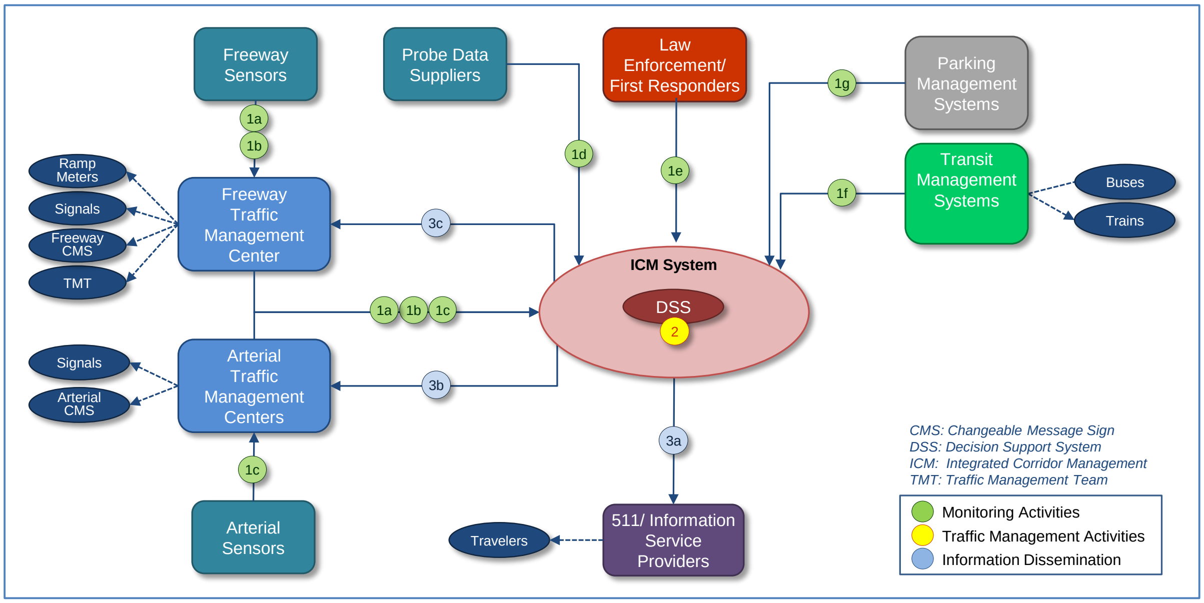

Figure 14-3 – No-Incident/No-Event Operation: Information Flow

3. **Traveler Information Dissemination** – Periodically, information collected by the ICM system is used to update traveler information for the corridor. This may include:
   a. Pushing travel times, parking availability and other information to the regional 511 system and other information providers.
   b. Posting updated travel times on freeway and arterial message signs
   c. Posting updated travel times or parking availability on select arterial changeable message signs

Table 14-1 describes the key roles and responsibilities of individual stakeholders in the scenario.

Table 14-1 – Roles and Responsibilities: No-Incident/No-Event Operation

Agency/Entity	Roles and Responsibilities
Caltrans	• Assess traffic conditions on freeway • Supply information to ICM system
Local cities	• Assess traffic condition on arterials under their jurisdiction • Supply information to ICM system
LA County	• Assess traffic conditions on arterials under its jurisdiction • Supply information to ICM system • Post incident-related messages on available arterial CMSs • Operate the Information Exchange Network (IEN)
Information Service Providers	• Supply probe vehicle data to the ICM system • Disseminate information to motorists via travel information applications, radio, or other media

14.2. SCENARIO 2 – MODERATE FREEWAY INCIDENT

This scenario considers a moderate, non-fatal accident occurring on the freeway during the afternoon peak period, causing one traffic lane to be blocked on the right side for more than 30 minutes and some congestion to build up on the general-purpose traffic lanes upstream of the incident location. Because of the resulting congestion, a certain proportion of motorists decide to seek an alternate route around the incident, using local arterials. Because of this increased traffic, some congestion starts to build as well on the local arterials near the incident location, causing additional delays to local traffic.

The operational goal of the ICM system in this scenario is to identify a suitable alternative route around the incident to accommodate the traffic exiting the freeway while minimizing effects on local traffic. It is assumed that how an incident is cleared is beyond the scope of the ICM system. The operational objective is to implement traffic control changes along an identified detour to facilitate travel along it and avoid gridlocking local traffic. This means changing traffic signal operations and freeway ramp metering along the identified detour to provide additional traffic carrying capacity. This effort may further be supported by posting messages on changeable message signs along the freeway to inform motorists of the incident and the available detour. Available changeable message signs or dynamic wayfinding signs along arterials may also be activated to indicate the route to follow to return to the freeway. Finally, it is assumed here that the incident is not extensive enough to warrant changes in transit services in the corridor.

The steps in this scenario are described in detail below. The step numbers correspond to the circled numbers in Figure 14-4 and Figure 14-5.

1. **Incident event** – An incident occurs on the eastbound direction of the freeway, causing one general-purpose traffic lane to be blocked on the right.

2. **Detection of changing traffic conditions** – Every 5 minutes the ICM system polls data from various monitoring systems to update its operational view of the corridor. As traffic starts to queue on the freeway upstream of the incident location, the ICM system starts picking up the following changes in traffic flow patterns:
    a. Mainline freeway traffic sensors close to the incident pick up an increase in congestion immediately upstream of the incident.
    b. Exit ramp sensors start to pick up an increase in volume as motorists choose to exit the freeway to use local arterials to go around the incident.
    c. As traffic on arterials near the freeway increases, arterial traffic sensors pick up an increase in traffic volume.
    d. Sensors on freeway on-ramps immediately downstream of the incident start to pick up an increase in traffic volume as motorists who have used the arterials to go around the incident seek to get back to the freeway.
    e. Collected probe vehicle data start to show changes in travel speed along freeway and arterial roadway segments, as well as some potential shifts in observed travel patterns.
    f. Operational data collected from transit management systems start to show some minor service delays building up along bus routes operating near the incident.
    g. Data collected from parking management systems show no significant changes in the occupancy of park-and-ride facilities.

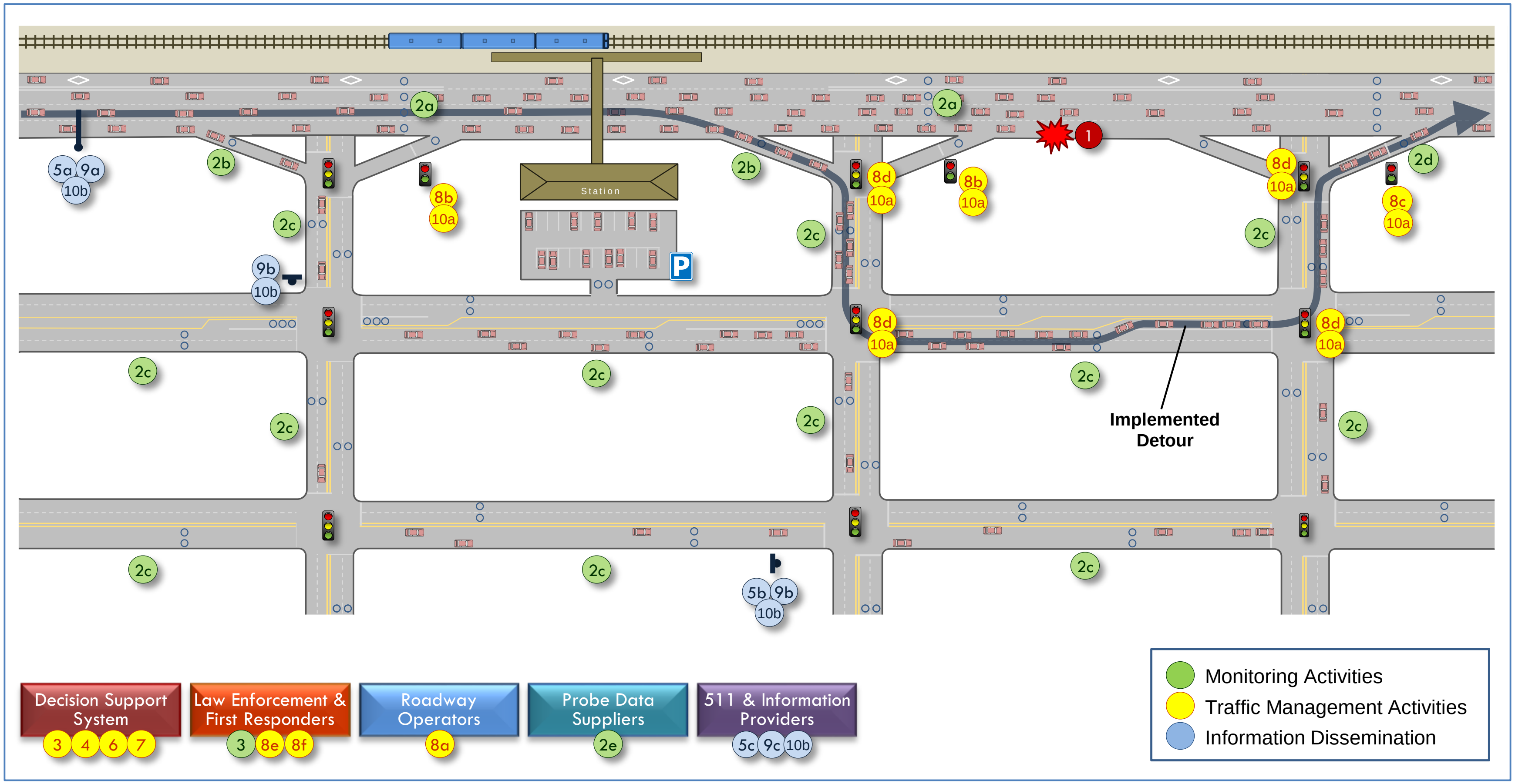

Figure 14-4 – Moderate Freeway Incident: Response Elements

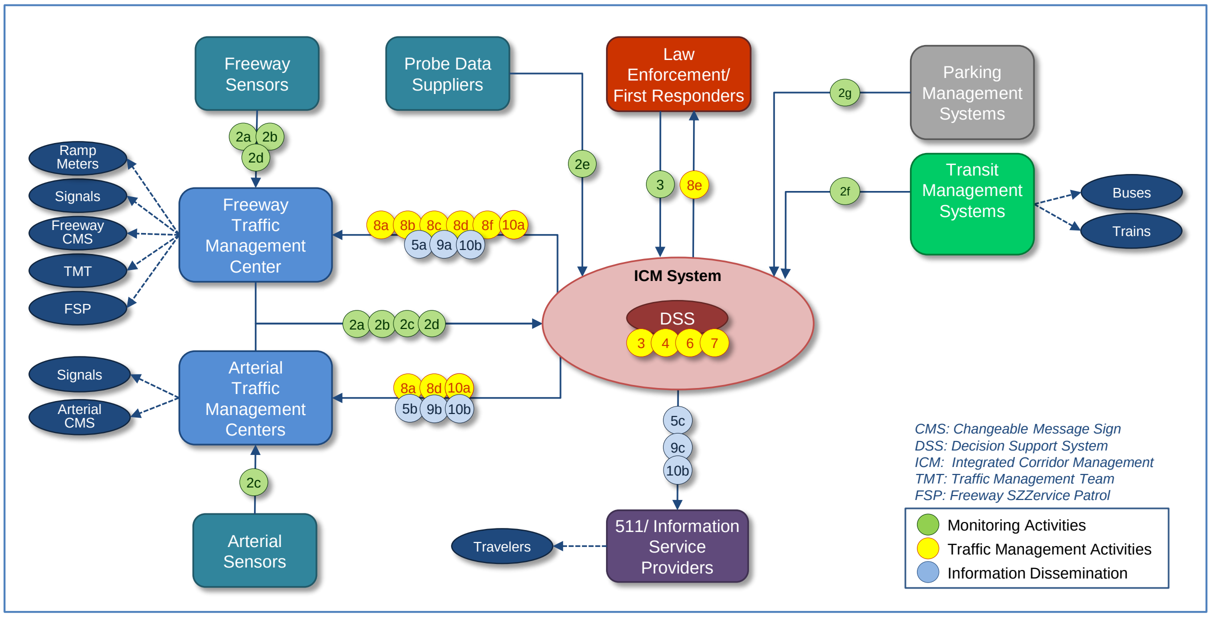

Figure 14-5 – Moderate Freeway Incident: Information Flow

3. **Incident identification** – Based on the analysis of traffic flow data received from freeway and arterials sensors, incident reports posted by the CHP on its CAD system, notifications provided by local law enforcement or first-responding agencies, or direct observations by ICM system operators, an incident event is logged into the ICM system. If the incident is first identified through the analysis of traffic flow data, a confirmation of its existence is then sought before allowing the ICM to further process the event. Depending on the location of the reported incident, this verification can be performed by ICM system operators by viewing real-time CCTV images, seeking confirmation from the CHP, or sending personnel to the field.

4. **Incident characterization** – After the occurrence of an incident has been verified, information about the incident is entered into the ICM system. This includes the location of the incident, the number of lanes affected, and a rough estimate of its expected duration. This information may be automatically fed from the CHP CAD system or manually entered into the ICM system by relevant system operators.

5. **Initial incident Information Dissemination –** Once the incident has been characterized, incident information is disseminated to motorists. This may include:
   a. Instructing Caltrans to post incident messages on freeway CMSs.
   b. Instructing local roadway operators to post incident messages on available arterial CMSs and/or dynamic trailblazer signs
   c. Pushing informational messages about the incident to the regional 511 system and various information providers.

6. **Initial impact assessment** – Once the incident has been characterized, the DSS predicts how traffic will be impacted in the corridor if nothing is done in terms of traffic management to respond to the incident. This becomes the base of evaluation of potential response plans.

7. **Response planning** – If the projected impacts exceed certain thresholds, the DSS develops a response plan to address the situation. No action would be taken if no significant impacts were projected. The response process starts with an assessment of traffic management devices that could participate in the response. Business rules agreed upon by all corridor stakeholders are then used to develop several candidate response plans. This process takes into account all active local constraints, such as school zones, low traffic areas, etc. The operational efficiency of each candidate response plan is subsequently evaluated using simulation or other analytic methods, and the plan resulting in the best overall performance for the corridor is recommended for implementation.

8. **Implementation of traffic management plan** – Based on the recommended response plan, control action requests are sent by the ICM system to the respective agencies controlling the traffic management assets targeted by the response plan. For the illustrated situation, this may imply the following control actions:
    a. Approval of the requested change by individual roadway operators, if required.
    b. Reducing the rate at which vehicles are allowed to enter the freeway at one or more on-ramps upstream of the incident.
    c. Increasing the rate at which vehicles are allowed to enter the freeway at the on-ramp at the end of the detour route.
    d. Implementing pre-approved signal timing plans at Caltrans, County and/or city-controlled signalized intersections along a recommended detour route to increase capacity in the direction of the added traffic.
    e. Providing, if necessary, information to CHP and local law enforcement officers on the detour that is being recommended by the ICM system and traffic managers.
    f. Informing the Metro Freeway Service Patrol of the location of the incident, if its assistance is needed to help clear the incident.

9. **Route information dissemination** – Based on the recommended response plan, information is disseminated to inform approaching freeway motorists of the recommended detour.
    a. In addition to posting information about the incident and its location, freeway CMSs close to the incident may provide a recommended detour, indicating which exit ramp, arterials and on-ramp to take to go around the incident.
    b. Available arterial CMSs, dynamic trailblazer signs, or static signs may be used to inform motorists on surrounding arterials of the recommended route to access the freeway or to get back to it.
    c. Information regarding the recommended detour is pushed out to the regional 511 system and interested information providers.

10. **Return to normal operation** – After an initial response plan has been implemented, the ICM system keeps tracking travel conditions in the corridor and, if needed, periodically adjusting elements of the plan. This is done by continuing polling data from various monitoring systems, periodically simulating travel conditions in the corridor, and developing new timing plans when given thresholds are met. After the incident is cleared, traffic sensors on the freeway and arterials

will pick up a gradual return to normal traffic conditions. Once certain traffic flow or delay thresholds are crossed, the ICM system will:

a. Send instructions to the various traffic management assets that have been used in the response plan to return to normal operation.

b. Disseminate updated travel information to 511 systems and information providers

Table 14-2 describes the key roles and responsibilities of individual stakeholders in the scenario

Table 14-2 – Roles and Responsibilities: Moderate Freeway Incident

Agency/Entity	Roles and Responsibilities
Caltrans	• Assess traffic conditions on freeway • Supply information to ICM system • Respond to and assist with incident clearance • Adjust ramp meters at selected freeway on-ramps and connectors • Adjust traffic signal operations at intersections under their jurisdiction (freeway ramp signals) • Post incident-related messages on freeway CMSs
Local cities	• Assess traffic condition on arterials under their jurisdiction • Supply information to ICM system • Adjust traffic signal operations at intersections under their jurisdiction • Post incident-related messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs
LA County	• Assess traffic conditions on arterials under its jurisdiction • Supply information to ICM system • Adjust traffic signals operations at intersections under its jurisdiction • Post incident-related messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs • Operate the Information Exchange Network (IEN)
California Highway Patrol	• Receive incident notification calls • Log incidents into the CHP Computer Aided Dispatch (CAD) system • Respond to the freeway incident • Where relevant, notify local agencies of the incident
Local law enforcement	• If relevant, receive information about the incident and recommended detour route from the ICM system. • If needed, assist in directing traffic along recommended detour.
Local First Responders	• If needed, respond to incident for fire suppression or medical assistance.
Information Service Providers	• Supply probe vehicle data to the ICM system • Disseminate information to motorists via travel information applications, radio, or other media

14.3. SCENARIO 3 – MAJOR FREEWAY INCIDENT

This scenario considers a major incident occurring on the freeway during the afternoon peak period, causing several traffic lanes to be blocked for a few hours. A major incident is defined here as an event causing the blockage of two or more traffic lanes for at least 30 minutes. Because of the lane blockage in a period of heavy traffic demand, congestion builds up on the freeway. This congestion then prompts an increasing number of motorists to seek an alternate route around the incident and to exit the freeway. In turn, due to the exiting freeway traffic, congestion starts to build on the surrounding arterials as well, creating additional delays for local traffic.

In the above context, the operational goal of the ICM system is to identify suitable alternative routes around the incident to accommodate the traffic exiting the freeway while minimizing impacts on local traffic. Depending on the amount of traffic exiting the freeway, the available traffic carrying capacity of surrounding arterials, and other operational constraints that may exist, one or more alternative routes may be identified. The objective here is to avoid gridlocking the surrounding arterials by spreading the traffic exiting the freeway to multiple arterials if necessary. For each of the identified routes, the system then seek to alter the operations of the traffic signals to provide additional traffic capacity in the direction of the detouring traffic and facilitate its return to the freeway. Information about the recommended detour is further disseminated to induce motorist to use the recommended route(s) and minimize traffic spillover to other arterials. For particularly long incidents, information about transit alternatives may also be disseminate to help reduce the overall motorized traffic demand put on the corridor.

For the above major freeway incident, the specific timeline of actions associated with the operation of the proposed ICM system is as illustrated in Figure 14-6 and Figure 14-7, and described in details below. Numbers in both figures refer to the number associated with each paragraph in the list below.

1. **Incident event** – A major incident occurs on the freeway in the eastbound direction, causing several lanes of the freeway to be blocked.

2. **Detection of changing traffic conditions** – Every 5 minutes the ICM system polls data from various monitoring systems to update its operational view of the corridor. As traffic starts to queue on the freeway upstream of the incident, the ICM system start pick up changes in traffic flow patterns through its periodical polling of data from connected traffic detection systems:
    a. Mainline freeway traffic sensors close to the incident pick up an increase in congestion immediately upstream of the incident.
    b. Exit ramp sensors start to pick up an increase in volume as motorists chose to exit the freeway to use local arterial to go around the incident.
    c. As traffic on arterials near the freeway increases, arterial traffic sensors pick up an increase in traffic volume.
    d. Sensors on freeway on-ramps immediately downstream of the incident start to pick up an increase in traffic volume as motorists who have used the arterials to go around the incident seek to get back to the freeway.
    e. Probe vehicle data collected from various sources start to show changes in travel speed along freeway and arterial roadway segments, as well as shifts in traveled routes.

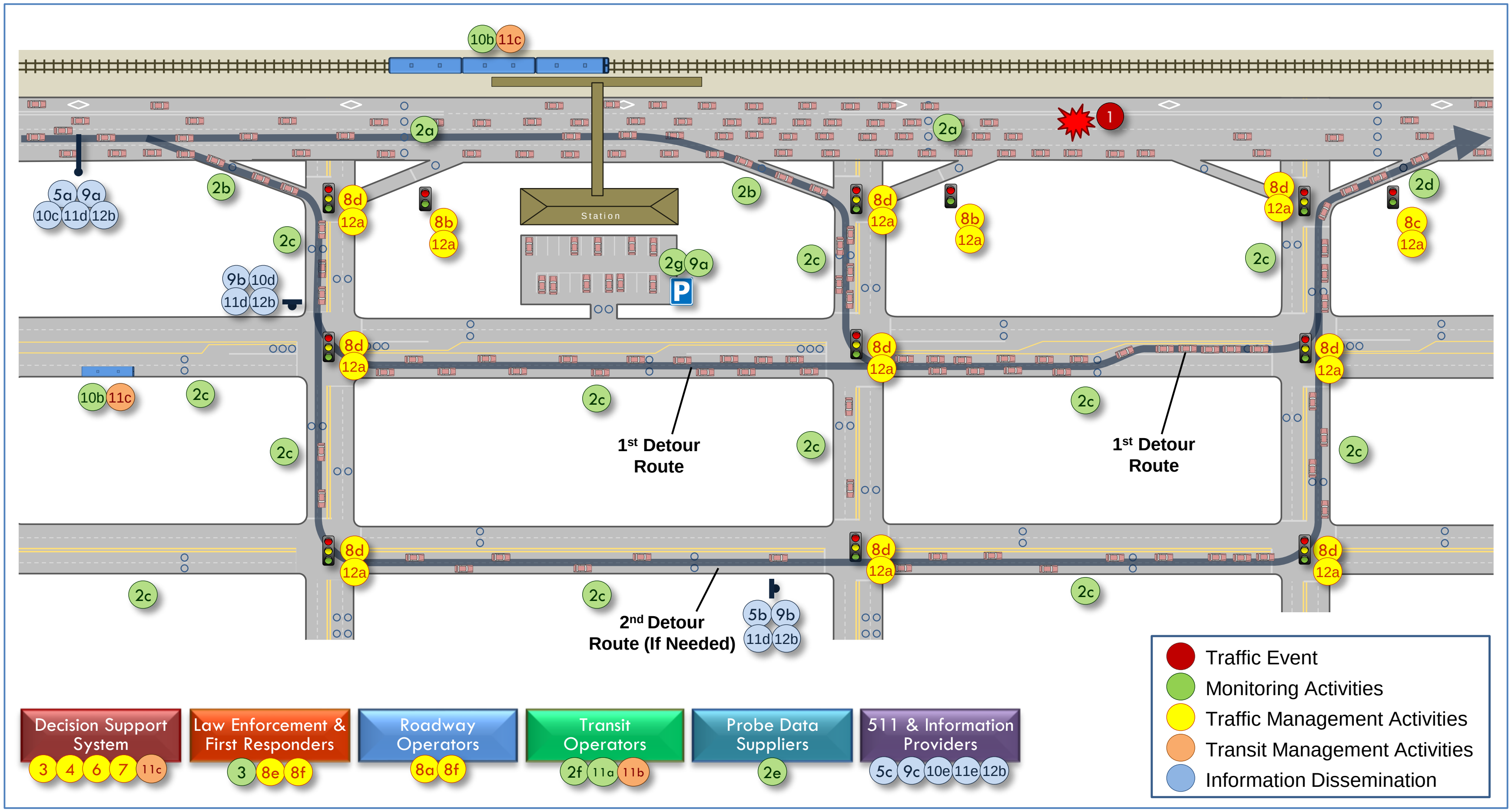

Figure 14-6 – Major Freeway Incident: Response Elements

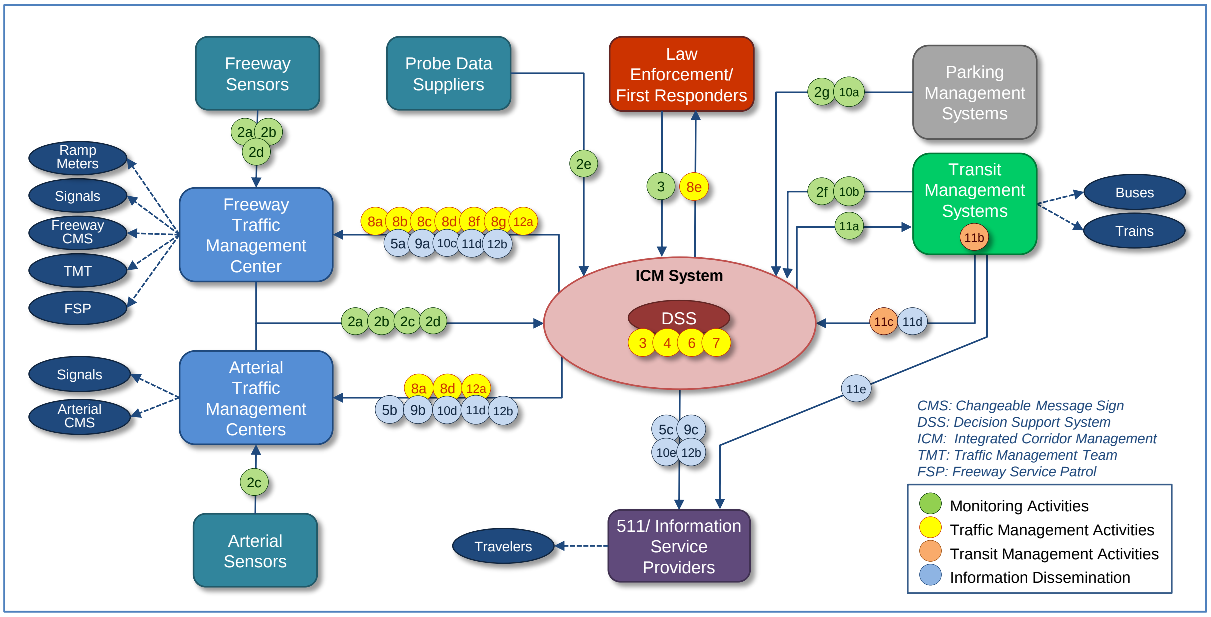

Figure 14-7 – Major Freeway Incident: Information Flow

f. Operational data collected from transit management systems start to show service delays building up along bus routes operating near the incident.

g. Data collected from parking management systems may show changes in the occupancy of park-and-ride facilities if the congestion caused by the incident entices motorists to take transit to reach their destination.

3. **Incident identification** – Based on the analysis of traffic flow data received from freeway and arterials sensors, incident reports posted by the CHP on its CAD system, notifications provided by local law enforcement or first-responding agencies, or direct observations by ICM system operators, an incident event is logged into the ICM system. If the incident is first identified through the analysis of traffic flow data, a confirmation of its existence is then sought before allowing the ICM to further process the event. Depending on the location of the reported incident, this verification can be performed by ICM system operators by viewing real-time CCTV images, seeking confirmation from the CHP, or sending personnel to the field.

4. **Incident characterization** – After the occurrence of an incident has been verified, information about the incident is entered into the ICM system. This includes the location of the incident, the number of lanes affected, and a rough estimate of its expected duration. This information may be automatically fed from the CHP CAD system or manually inputted into the ICM system by relevant system operators.

5. **Initial incident Information Dissemination –** Once the incident has been characterized, incident information is disseminated to motorists. This may include:

   a. Instructing Caltrans to post incident messages on freeway CMSs.

   b. Instructing local roadway operators to post incident messages on available arterial CMSs, and/or dynamic trailblazer signs.

   c. Pushing informational messages about the incident to the regional 511 system and various information providers.

6. **Initial impact assessment** – After the reported incident has been verified, information about the number of lanes closed and a rough estimate of its expected duration is gathered. This information may be automatically fed from the CHP CAD or manually entered into the system. Once the incident is characterized, the Decision Support System (DSS) predicts how traffic in the corridor will be impacted if nothing is done in terms of traffic management to respond to the incident. This becomes the basis for evaluating potential response plans.

7. **Response planning** – If the projected impacts exceed certain thresholds, the DSS develops a response plan to address the situation. (If no significant impacts were projected, no further action would be taken.) The response process starts with an assessment of traffic management devices that could participate in the response. Business rules agreed upon by all corridor stakeholders are subsequently used to develop several candidate response plans. This process takes into account all active local constraints, such as school zones, low traffic areas, etc. The operational efficiency of each candidate response plan is subsequently evaluated using simulation or other analytical methods, and the plan resulting in the best overall performance for the corridor is recommended for implementation.

8. **Implementation of traffic management plan** – Based on the recommended response plan, control action requests are sent by the ICM system to the respective agencies controlling the traffic management assets targeted by the response plan. For the current scenario, this may imply the following control actions:
   a. Approval of the requested change by individual roadway operators, if required.
   b. Reducing the rate at which vehicles are allowed to enter the freeway at on-ramps upstream of the incident.
   c. Increasing the rate at which vehicles are allowed to enter the freeway at on-ramps downstream of the incident located at the end of the recommended detour routes.
   d. Implementing pre-approved signal timing plans at Caltrans, county and/or city-controlled intersections along one or more detour routes. The number of routes considered depends on the volume of detouring traffic to be accommodated and the carrying capacity of available arterials. If a single detour is deemed sufficient, only one is implemented to minimize impacts on surrounding traffic. Multiple detours are considered if a single route alone cannot accommodate the detouring traffic. In the illustrated example, two detours are implemented: one along the arterial closest to the freeway and another one on the arterial further to the south.
   e. Providing, if necessary, information to CHP and local law enforcement officers on the detour that is being recommended by the ICM system and traffic managers.
   f. Dispatching Caltrans Traffic Management Team (TMT), if needed.
   g. Informing the Metro Freeway Service Patrol of the location of the incident, if its assistance is needed to help clear the incident.

9. **Route information dissemination** – Based on the recommended response plan, information is disseminated to inform approaching freeway motorists of the recommended detour.

a. In addition to posting information about the incident and its location, freeway CMSs close to the incident may provide a recommended detour, indicating which exit ramp, arterials and on-ramp to take to go around the incident.

b. Available arterial CMSs, dynamic trailblazer signs, and/or static signs may be used to inform motorists on surrounding arterials of the recommended route to access the freeway or to get back to it.

c. Information regarding the recommended detour is pushed out to the regional 511 system and interested information providers.

10. **Dissemination of information about alternative transit options** – Depending on the incident impacts, information about transit alternatives may be disseminated to corridor travelers by the ICM system. Preparation and dissemination of this information may include:

    a. Retrieving information from available parking management systems to assess parking availability at park-and-ride lots under ICM surveillance.

    b. Retrieving relevant operational information, including planned service deviations, from transit agencies.

    c. Posting of messages indicating the location of available park-and-ride lots on freeway CMSs; comparative travel times between transit and driving to specific destination may also be posted if deemed more appropriate.

    d. Using arterial CMSs, dynamic trailblazer signs, and/or static signs to guide motorists to the nearby park-and-ride lots.

    e. Pushing information about alternative transit options to the regional 511 system and relevant information providers.

11. **Transit service adjustments** – After having being informed of the incident, dispatchers managing transit services in the corridor use the ICM system keep track of the situation and assess whether service changes should implemented. The following are specific activities that may be conducted by transit dispatchers and the ICM system for managing potential service changes:

    a. Following reception of the incident notification, dispatchers connect to the ICM system to assess how local traffic is impacted. They also review operational data from the buses and light-rail trains in service to assess the magnitude of any resulting service deviations.

    b. Based upon their expert judgment, and possibly recommendations from the DSS, transit dispatchers decide to implement temporary service adjustments

    c. Transit dispatchers communicate the adopted service changes to relevant vehicle operators and input them into the ICM system to allow it to consider their impacts on corridor evaluations.

    d. If relevant, transit agency staff input requests into the ICM system to post messages on freeway or arterial CMSs to inform the traveling public of the transit service changes.

    e. Information about the adopted service changes is directly communicated by the transit agency to the regional 511 system and relevant information providers.

12. **Return to normal operation** – After an initial response plan has been implemented, the ICM system keeps tracking travel conditions in the corridor and, if needed, periodically adjusting

elements of the response plan. This is done by continuing to poll data from various monitoring systems every 5 minutes, simulating every 15 minutes travel conditions in the corridor, and developing new timing plans when given thresholds are met. After the incident is cleared, traffic sensors on the freeway and arterials will pick up a gradual return to normal traffic conditions. Once certain traffic flow or delay thresholds are crossed, the ICM system will:

a. Send instructions to the various traffic management assets that have been used in the response plan to return to normal operation.

b. Disseminate updated travel information to 511 systems and information providers

Table 14-3 describes the key roles and responsibilities of individual stakeholders in the scenario.

Table 14-3 – Roles and Responsibilities: Major Freeway Incident

Agency/Entity	Roles and Responsibilities
Caltrans	• Assess traffic conditions on freeway • Supply information to ICM system • Respond to and assist with incident clearance • Adjust ramp meters at selected freeway on-ramps and connectors • Adjust traffic signal operations at intersections under their jurisdiction (mostly freeway ramp signals) • Post incident-related messages on freeway CMSs
Local cities	• Assess traffic condition on arterials under their jurisdiction • Supply information to ICM system • Adjust traffic signal operations at intersections under their jurisdiction • Post incident-related messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs
LA County	• Assess traffic conditions on arterials under its jurisdiction • Supply information to ICM system • Adjust traffic signal operations at intersections under its jurisdiction • Post incident-related messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs • Operate the Information Exchange Network (IEN)
Transit agencies	• Assess transit operations in the corridor • Assess parking availability at park-and-ride lots (where available) • Supply information to ICM system • Adjust transit services if appropriate
California Highway Patrol	• Receive incident notification calls • Log incidents into the CHP Computer Aided Dispatch (CAD) system • Respond to the freeway incident • Where relevant, notify local agencies of freeway incidents having the potential to impacting local traffic
Local law enforcement	• If relevant, receive information about the incident and recommended detour route from the ICM system • If needed, assist in directing traffic along recommended detour
Local First Responders	• If needed, respond to incident for fire suppression, medical assistance, or victim extraction
County emergency services	• Respond to accidents with fatalities
Information Service Providers	• Supply probe vehicle data to the ICM system • Disseminate information to motorists via travel information applications, radio, or other media

14.4. SCENARIO 4 – MAJOR ARTERIAL INCIDENT

This scenario considers a major incident occurring in the peak traffic direction on one of the arterials parallel to the freeway, causing a roadway segment to be fully blocked for one hour. Because of segment shutdown in a period of heavy traffic, congestion quickly builds up on the arterial and surrounding arterials.

The operational goal of the ICM system is to identify suitable alternative routes around the incident. Depending on the location of the incident, its severity, the amount of traffic to reroute, and the available traffic carrying capacity of surrounding arterials, the ICM system may recommend sending arterial traffic onto the freeway to bypass the accident. In such a case, the system would seek to alter the operation of traffic signals at arterial intersections and the flow metering rates on freeway on-ramps along selected route(s) to increase the carrying capacity of the identified detour(s). Available arterial changeable message signs may further be used to inform motorists of the detour. Similarly, messages may be posted on freeway changeable message signs to inform motorists on the freeway of the incident on the arterial and suggest an alternate exit. During the incident, transit agencies may further use data provided by the ICM system to assess potential impacts on bus operations and to implement service changes, if needed.

The steps in this scenario are described in detail below. The step numbers correspond to the circled numbers in Figure 14-8 and Figure 14-9.

1. **Incident event** – A major incident occurs in the eastbound direction on the closest arterial to the freeway, causing all lanes to be blocked on a segment linking two major intersections.

2. **Detection of changing traffic conditions** – Every 5 minutes the ICM system polls data from various monitoring systems to update its operational view of the corridor. As traffic starts to queue on the arterial and surrounding cross streets, the ICM system starts picking up changes in traffic flow patterns:
    a. Arterial detectors upstream of the incident start to show a decrease in traffic volume.
    b. Arterial detectors downstream of the incident also show a decrease in traffic volume.
    c. Detectors on surrounding arterials may initially show an increase in volume as an increasing number of motorists seek to detour around the incident. As congestion builds up on these arterials, observed traffic volumes may in turn start to drop as well.
    d. After a certain time, traffic detectors on freeway exit ramps upstream of the incident may start to see a reduction in traffic volume if the congestion generated by the incident propagates to them. Flow on exit ramps downstream of the incident may also show some traffic increase as some freeway motorists decide to take another exit after observing unusual congestion on the ramp they normally take.
    e. Detectors on freeway on-ramps upstream of the incident may start to see an increase in volume as some motorists seek to use the freeway to go around the incident. Traffic increase may also be observed at on-ramps downstream of the incident from motorists electing to take a different ramp to enter the freeway after having observed usual congestion.
    f. If congestion effects propagates to the freeway, mainline freeway traffic sensors may register slight changes in traffic speeds or traffic volumes on curb lanes.

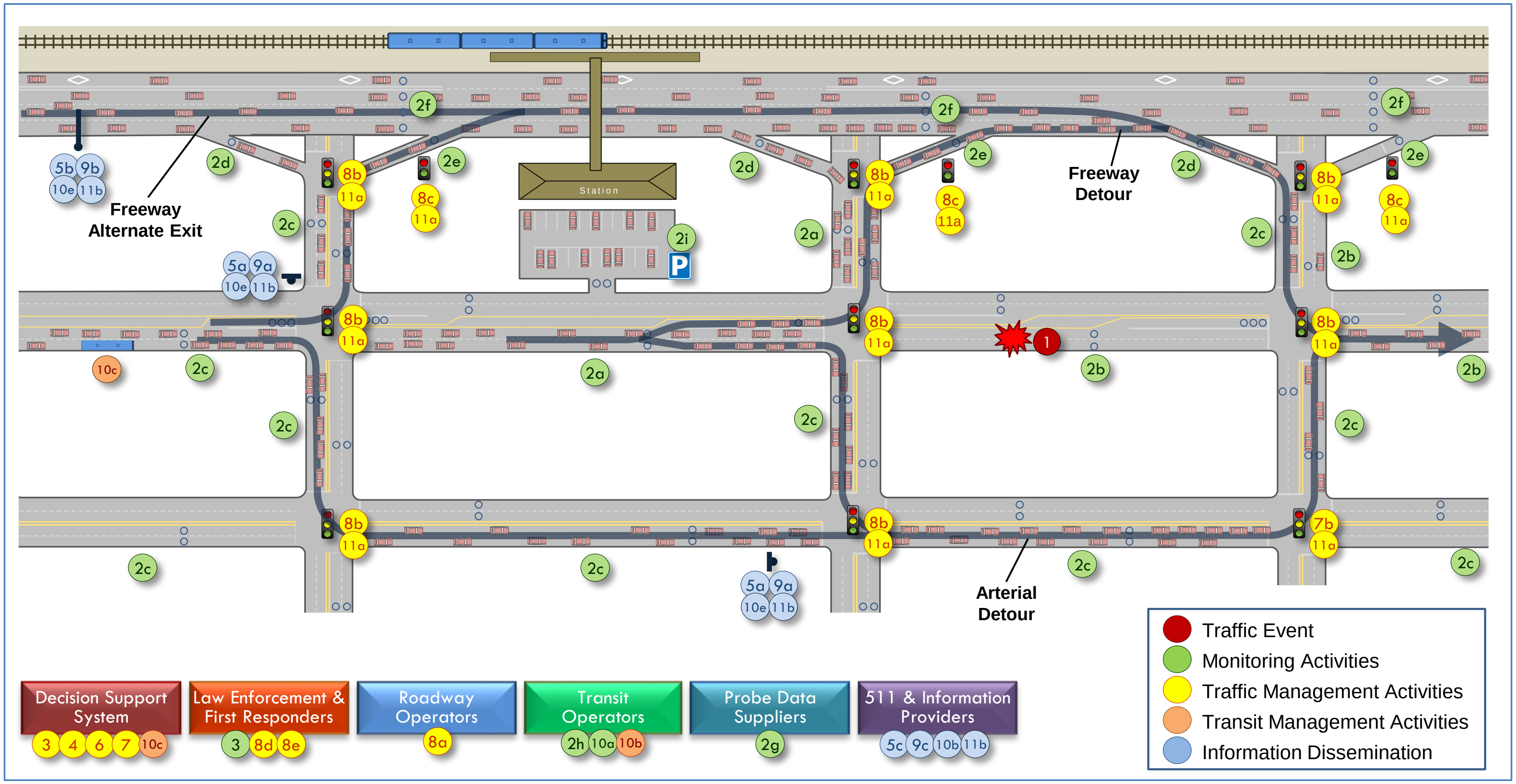

Figure 14-8 – Major Arterial Incident: Response Elements

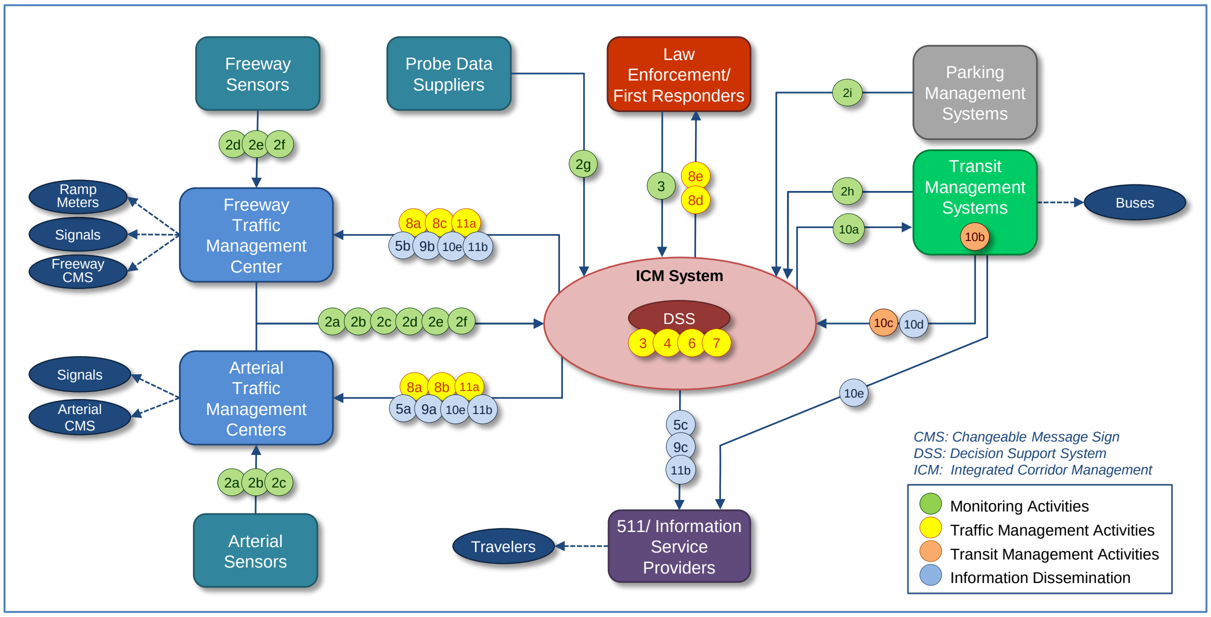

Figure 14-9 – Major Arterial Incident: Information Flow

g. Over time, probe vehicle data collected from various sources start to show changes in travel speed along and around the arterial affected by the incident, as well as some potential shifts in observed travel patterns.

h. Operational data collected from transit management systems may show service delays building up along bus routes operating near the incident.

i. In this scenario, it is assumed that parking occupancy data do not show significant changes in occupancy rates.

3. **Incident identification** – Based on the analysis of traffic flow data received from freeway and arterials detectors, incident reports provided by local law enforcement or first-responding agencies, or direct observations made by ICM system operators, an incident event is logged into the ICM system. If the incident is first identified through the analysis of traffic flow data, a confirmation of its existence is then sought before allowing the ICM to further process the event. Depending on the location of the reported incident, this verification can be performed by ICM system operators by viewing real-time CCTV images, seeking confirmation from relevant first responding agencies, or by sending personnel to the field.

4. **Incident characterization** – After the occurrence of an incident has been verified, information about the incident is entered into the ICM system. This includes the location of the incident, the number of lanes affected, and a rough estimate of its expected duration. This information may be automatically fed from the CHP CAD system or manually entered into the ICM system by relevant system operators.

5. **Initial incident Information Dissemination –** Once the incident has been characterized, incident information is disseminated to motorists. This may include:

   a. Instructing local roadway operators to post incident messages on available arterial CMSs.

   b. Instructing Caltrans to post incident messages on freeway CMSs.

   c. Pushing informational messages about the incident to the regional 511 system and various information providers.

6. **Initial impact assessment** – After the incident has been verified, information about the number of lanes closed and a rough estimate of its expected duration is gathered. Depending on the source, this data may be automatically fed or manually entered. Once the incident is characterized, the DSS predicts how traffic will be impacted in the corridor if nothing is done in terms of traffic management to respond to the incident. This becomes the basis for evaluating potential response plans.

7. **Response planning** – If the projected impacts exceed certain predefined thresholds, the DSS develops a response plan to address the situation. This process starts with an assessment of traffic management devices that could participate in the response. Business rules agreed upon by all corridor stakeholders are subsequently used to develop several candidate response plans. This process takes into account all active local constraints, such as school zones, low traffic areas, etc. The operational efficiency of each candidate response plan is subsequently evaluated using simulation or other analytical methods, and the plan resulting in the best overall performance for the corridor is recommended for implementation.

8. **Implementation of traffic management plan** – Based on the recommended response plan, control action requests are sent by the ICM system to the respective agencies controlling the traffic management assets targeted by the plan. For the current scenario, this may imply:
   a. Approval of the requested change by individual roadway operators, if required.
   b. Implementing pre-approved signal timing plans at Caltrans-, county-, and/or city-controlled signalized intersections along one or more detour routes. The number of detour routes implemented depends on the volume of traffic being detoured and the available spare traffic capacity along the various possible detours. If a single detour is deemed sufficient, only one is implemented to minimize impacts on local traffic. More than one detour is considered if a single route alone cannot accommodate the detouring traffic. In this case, two detours are implemented: one along the arterial to the south of the incident and one along the freeway to the north.
   c. Increasing the rate at which vehicles are allowed to enter the freeway at on-ramps immediately upstream of the incident.
   d. Providing information to local law enforcement officers on the detour that has been recommended by the ICM system and approved by corridor traffic managers.
   e. Informing CHP officers of the plan to use the freeway as a detour around an arterial incident.

9. **Route information dissemination** – Based on the recommended response plan, information is disseminated to inform motorists of the recommended route around the incident.
   a. Available arterial CMSs, dynamic trailblazer signs, and/or static signs are used to inform motorists on affected arterials of the recommended detour around the incident.
   b. In addition to posting information about the incident and its location, freeway CMSs close to the incident may provide a recommended detour, indicating which exit ramp, arterials, and on-ramp to take to go around the incident.

   c. Information regarding the incident and the recommended detour around it is pushed out to the regional 511 system and relevant information providers.

10. **Transit service adjustments** – On receiving notification of the incident, transit dispatchers use the ICM system to keep track of the situation and implement, if needed, transit service adjustments. The following activities may be conducted by transit dispatchers and the ICM system for managing potential service changes:

    a. Following reception of the incident notification, dispatchers connect to the ICM system to assess how local traffic is impacted by the incident. They also review operational data from the buses and light-rail trains in service to assess the magnitude of any resulting service deviations.

    b. Based on their expert judgment, and possibly recommendations from the DSS, dispatchers decide to implement temporary service adjustments.

    c. Service changes are communicated to the relevant vehicle operators by transit dispatchers and entered into the DSS.

    d. If relevant, requests are entered into the ICM system to post messages on arterial CMSs to inform the traveling public of the transit service changes.

    e. Information about the adopted service changes is directly communicated by the transit agency to the regional 511 system and relevant information providers.

11. **Return to normal operation** – After an initial response plan has been implemented, the ICM system keeps tracking travel conditions in the corridor and, if needed, periodically adjusting elements of the response plan. This is done by continuing to poll data from various monitoring systems every 5 minutes, simulating travel conditions in the corridor every 15 minutes, and developing new timing plans when given thresholds are met. After the incident is cleared, traffic detectors on the arterials and freeway will pick up a gradual return to normal traffic conditions. Once certain traffic flow or delay thresholds are crossed, the ICM system will:

    a. Send instructions to the various traffic management assets that have been used in the response plan to return to normal operation.

    b. Disseminate updated travel information to 511 systems and information providers.

Table 14-4 describes the key roles and responsibilities of individual stakeholders for this scenario.

Table 14-4 – Roles and Responsibilities: Major Arterial Incident

Agency/Entity	Roles and Responsibilities
Caltrans	• Assess traffic conditions on freeway • Supply information to ICM system • Adjust ramp meters at selected freeway on-ramps and connectors • Adjust traffic signal operations at intersections under their jurisdiction (mostly freeway ramp signals) • Post incident-related messages on freeway CMSs
Local cities	• Assess traffic conditions on arterials under their jurisdiction • Supply information to ICM system • Adjust traffic signal operations at intersections under their jurisdiction • Post incident-related messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs
LA County	• Assess traffic conditions on arterials under its jurisdiction • Supply information to ICM system • Adjust traffic signal operations at intersections under its jurisdiction • Post incident-related messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs • Operate the Information Exchange Network (IEN)
Transit agencies	• Assess transit operations in the corridor • Adjust transit services if appropriate • Supply information to ICM system
California Highway Patrol	• If needed, assist with managing traffic on freeway ramps and the freeway mainline.
Local law enforcement	• Receive incident notification calls • Inform the ICM system of incidents • Respond to the incidents occurring on arterials • If needed, assist in directing traffic along recommended detour(s)
Local First Responders	• If needed, respond to incident for fire suppression, medical assistance, or victim extraction
County emergency services	• Respond to accidents with fatalities
Information Service Providers	• Supply probe vehicle data to the ICM system • Disseminate information to motorists via travel information applications, radio, or other media

14.5. SCENARIO 5 – SPECIAL EVENT

This scenario considers how the ICM system would respond to special events occurring in the corridor, as well as events occurring outside the corridor but affecting traffic in it. Examples of special events considered in this scenario include:

- Major weekday event impacting AM and/or PM peak traffic
- Major weeknight sporting event
- Major event on weekend
- Highway maintenance or construction activity requiring lane closures on the freeway or surrounding arterials
- Special events causing the closure of major streets (generally on holidays or weekends), such as the Rose Parade, arts festivals, or street fairs
- Major holiday events, such as Fourth of July fireworks displays, pre-Christmas surges at shopping malls, etc.
- Transit strike

A key distinction between this scenario and the incident scenarios described earlier is the planned nature of the events considered. Because event occurrence is known some time ahead, there is an opportunity to implement traffic and transit management plans specifically designed for the event, or to use different thresholds at which specific pre-approved plans are implemented when compared to normal operations. Similar to how the system would responds to incidents, a capability would also be provided to react to unexpected situations. For instance, while traffic surges associated with sporting events can be projected from observations from prior similar events, worse than anticipated traffic conditions could occur because of incidents, unexpected road closure for emergency repair, inclement weather, or other situations. In such cases, the ICM system could perform evaluations to assess whether modifications to the original special event plan should be considered, if possible, to improve corridor operations.

The steps in this scenario are described in detail below. The step numbers correspond to the circled numbers in Figure 14-10 and Figure 14-11.

1. **Event planning** – Several weeks or months prior to a planned event, the event coordinator and agencies that are expected to have their operations affected by the event develop a special travel management plan for the event. The developed plan outlines the roadway(s) expected to be affected by the event and the traffic control and transit management strategies that should be implemented on various corridor roadways, as well as any supporting informational campaign, to help manage the travel demand that the event is expected to generate and the travel constraints it will impose on other corridor activities.

2. **Base ICM response setup** – Upon completion of the planning phase, information about the event and its associated travel management plan is entered into the ICM system. The information entered includes the date of the event, what signal timing plan should be run during the event on each affected arterial, what criteria is to be used to trigger the activation of a specific timing plan (time of day, specific flow threshold, etc.), messages to be posted on freeway and arterial changeable message signs, etc. This information may be entered by a single ICM operator acting on behalf of all affected agencies or by representative from each affected agency.

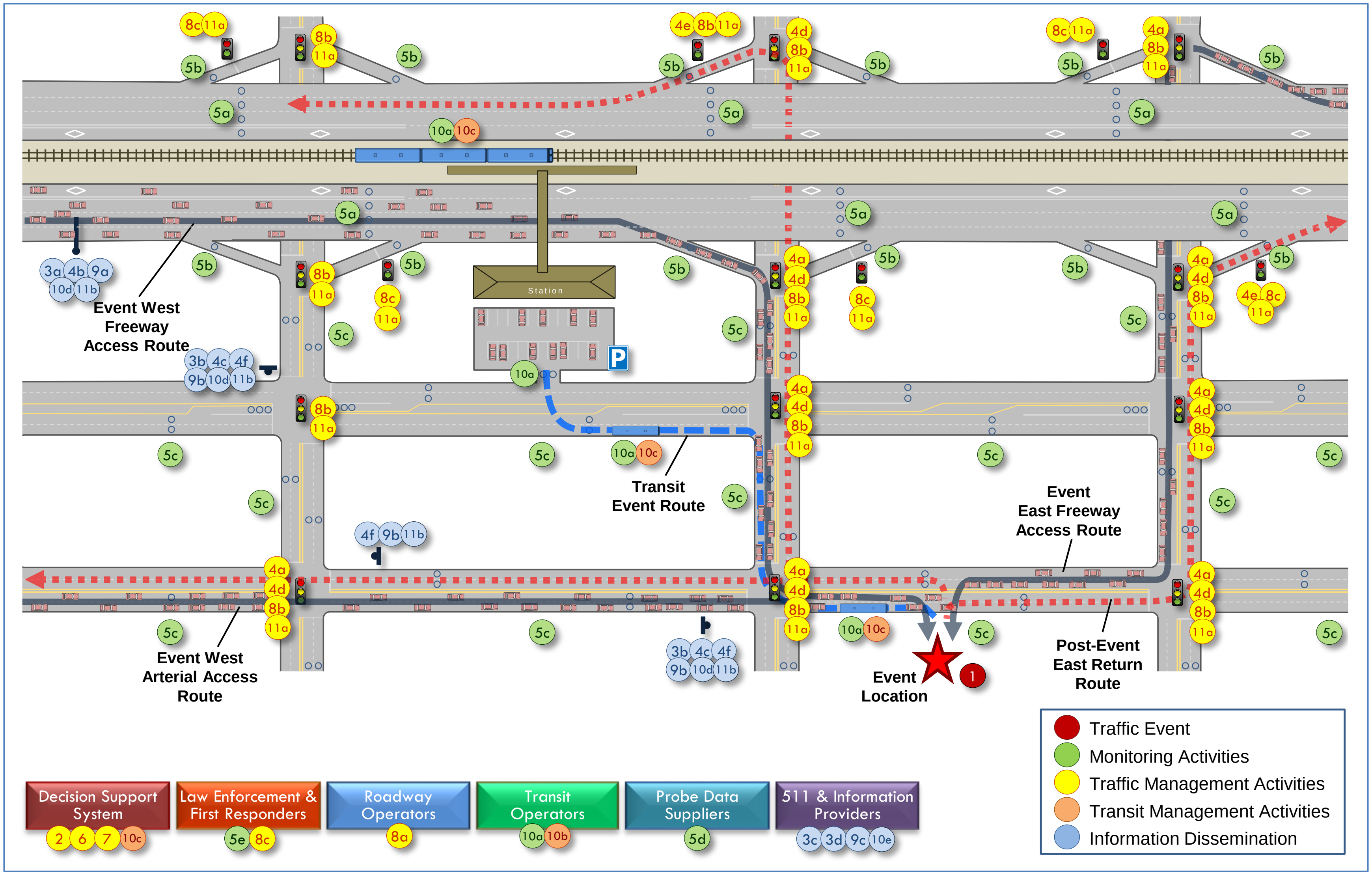

Figure 14-10 – Special Event: Response Elements

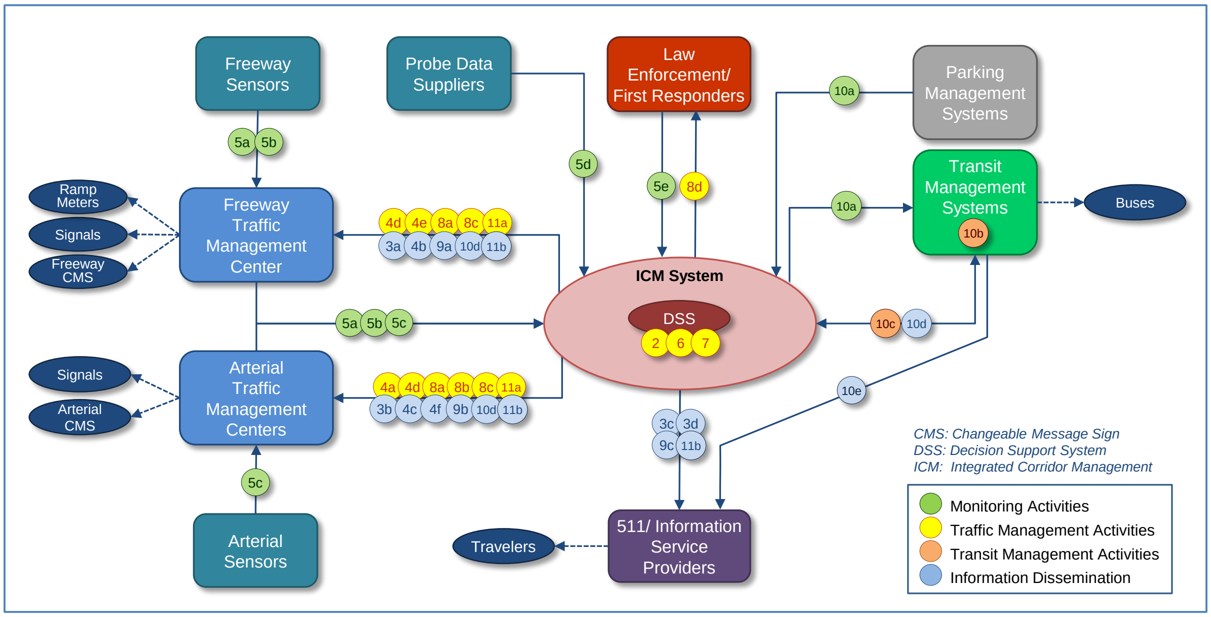

Figure 14-11 – Special Event: Information Flow

3. **Pre-event informational campaign** – On the day of the event or several days prior to it, the ICM system start to disseminate information about the event to warn motorists about potential travel difficulties along the corridor due to event traffic. This may involve:
    a. Posting travel advisory messages on freeway CMS
    b. Posting travel advisory messages on arterial CMS having the capability to display such messages
    c. Pushing travel advisory messages on 511 services
    d. Providing event information to information providers
4. **Implementation of event management plan on event day** – On the day of the event, the ICM system automatically implements the base elements of the special event response plan that has been coded in it. Prior to the start of the event, this includes:
    a. Activating planned signal timing plans at signalized intersections along routes leading to the event to provide additional traffic capacity in the direction of the event.
    b. Posting pre-approved messages on freeway CMSs informing motorists of the recommended exit(s) and route(s) to the event.
    c. Posting messages on arterial CMS and/or dynamic trailblazer signs directing traffic to the event site.

    Prior to the end of the event, additional activities executed by the ICM system include:

    d. Activating planned timing plans at intersections along the routes that have been selected to lead traffic away from the event to provide additional traffic carrying capacity in that direction.
    e. If relevant, changing ramp metering rates at freeway on-ramps at the end of the selected event evacuation routes.

   f. Posting messages on arterial CMSs and/or dynamic trailblazer signs directing traffic back to the freeway.

5. **Tracking of travel conditions during event** – From the start to the event management period, the ICM system polls every 5 minutes data from various monitoring systems to update its operational view of the corridor. Collected data include:

   a. Data from mainline freeway sensors, to track traffic flow conditions on the freeway.

   b. Data from freeway on-ramps and off-ramps, to track freeway entry and exit demands, as well as traffic queues that may form on the ramps.

   c. Data from arterial sensors reporting traffic flows, to track traffic flow conditions on corridor arterials.

   d. Probe vehicle data from data suppliers, to track travel times or speed profiles along specific routes, as well as to assess potential changes in routing patterns.

   e. Incident reports from CHP and local law enforcement and first responding agencies, to assess whether incidents are influencing travel conditions in the corridor.

   Any unusual situation identified in the data streams is flagged and analyzed to determine whether it may be the result of an incident. Should the data indicate the potential occurrence of an incident, a warning message is then sent to the ICM operator for verification.

6. **Periodical projection of corridor operations** – Throughout the event, the ICM system uses the collected traffic flow and probe vehicle data to update a simulation model of the corridor. This model is then run every 15 minutes to project traffic conditions over the corridor over the next hour. Simulation projections are then provided to the ICM operators to help them assess how the corridor is operating under the predefined response plan when considering the observed travel demand and any incident that may have occurred.

7. **ICM response planning for unexpected situations** – If observed traffic volumes, travel times, or delays are found to exceed specific thresholds, the DSS starts to develop alternate response plans to address the situation. Similar to the management of incidents, this process starts with an assessment of traffic management devices that could participate in a response. Business rules agreed upon by all corridor stakeholders are subsequently used to develop several candidate response plans. This process takes into account all active local constraints, such as school zones, low traffic areas, etc. The operational efficiency of each candidate response plan is subsequently evaluated using simulation or other analytical methods, and the plan resulting in the best overall performance for the corridor is recommended for implementation.

8. **Implementation of recommended management plan to address unexpected situations** – Based on the recommended response plan, control action requests are sent by the ICM system to the agencies controlling the traffic management assets targeted by the selected response plan. For the current scenario, this may lead to the following actions:

   a. Approval of the requested change by individual roadway operators, if required.

   b. Implementing pre-approved signal timing plans at Caltrans-, county-, and/or city-controlled signalized intersections for maximum traffic flow capacity in the direction of traffic going to the event or returning from it, depending on when the change is recommended. This may include changes at intersections that are not part of the planned event access routes.

c. Increasing the rate at which vehicles are allowed to enter the freeway at on-ramps used by traffic coming back from the event to reduce or prevent queuing on nearby arterials. This may again include on-ramp meters that are not part of the planned event routes.

d. Informing the CHP and/or local law enforcement agencies of the preferred routes that have been identified by the ICM system to go to the event or return from it and that has been approved by corridor traffic managers.

e. Providing information to the CHP and/or local law enforcement officers on where traffic should be directed to go to reach the event site from the freeway or to access the freeway from the event site.

9. **Dissemination of updated routing information** – Based on the recommended response plan, information is disseminated to inform freeway and arterial motorists of the incident and to inform them of the recommended detour.

    a. Messages informing freeway motorists about the best routes to take to reach the event based on observed traffic conditions are posted by Caltrans on CMSs along the freeway.

    b. Available arterial CMSs, dynamic trailblazer signs, and/or static signs may be used to direct traffic along the best routes to reach the event site or to travel back from it to the freeway.

    c. Information regarding the recommended routes to take to go to the event and come back from it may be pushed to the regional 511 system and interested information providers.

10. **Transit service adjustments to unplanned situations** – During the event, transit dispatchers use the ICM system to assess periodically whether service changes should be implemented. The following activities may be conducted by transit dispatchers and the ICM system for managing potential service changes:

    a. During the event, transit dispatchers periodically check existing and projected traffic flow conditions produced by the ICM system to review the adequacy of the planned transit services for the event. They also review operational data from buses and light-rail trains in service to assess any service deviations. Where possible, available parking occupancy data is also reviewed to assess parking availability at park-and-ride lots.

    b. Based on the data collected, their expert judgment, and possibly recommendations from the DSS, transit dispatchers decide whether to alter transit service to the event.

    c. Service changes are communicated to the relevant vehicle operators and entered into the ICM system to allow the system to consider these changes in future corridor evaluations.

    d. If relevant, requests are entered into the ICM system to post on freeway or arterial CMSs messages to inform the traveling public of the transit service changes.

    e. If relevant, transit operators push messages about the transit service changes directly to the regional 511 system and relevant information providers.

11. **Return to normal operation** – After an initial response plan has been implemented, the ICM system keeps tracking travel conditions in the corridor and, if needed, periodically adjusting

elements of the plan. This is done by continuing polling data from various monitoring systems periodically simulating travel conditions in the corridor, and developing new timing plans when given thresholds are met. After the close of the event, traffic detectors on the arterials and freeway will pick up a gradual return to normal traffic conditions. Once certain traffic flow or delay thresholds are crossed, the ICM system will:

a. Send instructions to the various traffic management assets that have been used to return to normal operation.

b. Disseminate updated travel information to 511 systems and information providers

Table 14-5 describes the key roles and responsibilities of individual stakeholders for this scenario.

Table 14-5 – Roles and Responsibilities: Special Event

Agency/Entity	Roles and Responsibilities
Caltrans	• Collaborate on the development of special event travel management plan • Assess traffic conditions on freeway • Supply information to ICM system • Adjust ramp meters at selected freeway on-ramps and connectors • Adjust traffic signal operations at intersections under their jurisdiction (mostly freeway ramp signals) • Post travel information messages on freeway CMSs
Local cities	• Collaborate on the development of special event travel management plan • Assess traffic condition on arterials under their jurisdiction • Supply information to ICM system • Adjust traffic signal operations at intersections under their jurisdiction • Post guidance messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs
LA County	• Collaborate on the development of special event travel management plan • Assess traffic conditions on arterials under its jurisdiction • Supply information to ICM system • Adjust traffic signals operations at intersections under its jurisdiction • Post guidance messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs • Operate the Information Exchange Network (IEN)
Transit agencies	• Collaborate on the development of special event travel management plan • Assess transit operations in the corridor • Adjust transit services if appropriate • Supply information to ICM system
California Highway Patrol	• Collaborate on the development of special event travel management plan • If needed, assist with managing traffic on getting on and off the freeway • Inform Caltrans of incidents occurring on the freeway system, if any • Response to incidents occurring on the freeway and freeway ramps, if any
Local law enforcement	• Collaborate on the development of special event travel management plan • If needed, assist in directing traffic along recommended detour(s). • Inform the ICM system of incidents occurring on local arterials, if any • Respond to the incidents occurring on arterial, if any
Local First Responders	• If needed, respond to incidents occurring in the corridor for fire suppression, medical assistance, or victim extraction.
Information Service Providers	• Supply probe vehicle data to the ICM system • Disseminate information to motorists via travel information applications, radio, or other media

14.6. SCENARIO 6 – MAJOR TRANSIT INCIDENT

This scenario considers how the ICM system would respond to a major transit incident significantly affecting travel conditions in the corridor. For the I-210 corridor, an example might be a situation forcing a significant reduction in service, or even a full closure, along the Gold light-rail line during the morning peak hour for several hours. Such interruptions can be caused by train mechanical failures, problems with the overhead system delivering power to trains, traffic incidents resulting in the damage of rail or electrical equipment, traffic incidents occurring at grade crossings, or local law enforcement action.

This scenario is unique in that the initial response to the transit incident is expected to be provided by transit agency staff. Following an incident significantly affecting transit service, it is expected that staff from the affected transit agency would identify the appropriate changes in transit services to address the situation and implement the developed transit response plan. In this context, the primary role of the ICM system is to keep monitoring traffic conditions in the corridor to assess whether roadway closures associated with the transit incident or changes in traffic flow resulting from the reduction of transit service warrants changes in the existing traffic and travel management strategies.

The steps in this scenario, where an incident forces the shutdown of the Gold Line, are described in detail below. The step numbers correspond to the circled numbers in Figure 14-12 and Figure 14-13.

1. **Incident occurrence** – A problem with the system delivering electricity to the trains running along the Gold Line forces the complete shutdown of the line for several hours at the beginning of the morning peak period.

2. **Incident Information Dissemination** – Immediately after having been informed of the incident, staff from the transit agency inputs information regarding the incident into the ICM system.

3. **Transit agency incident response planning** – Following the incident, Metro decides to put in place a temporary bus service to replace the transit service normally provided by the light-rail trains.

4. **Implementation of initial transit response plan** – Implementation of the response plan developed by the bus agency involves:
   a. Putting into service buses that will be running from train station to train station along one of the corridor arterials running parallel to the tracks.
   b. Entering information into the ICM system about the temporary bus service to allow it to account for the new service in its corridor evaluations.
   c. Instructing the ICM system to place relevant messages freeway and/or arterial CMSs
   d. Pushing messages directly to the regional 511 system and relevant information providers.

5. **Tracking of travel conditions** – After being informed of the incident, the ICM system periodically assesses travel conditions in the corridor by collecting and processing data from the following traffic monitoring systems every 5 minutes:
   a. Freeway mainline traffic sensors, to assess potential changes in freeway traffic.
   b. Freeway on-ramp and off-ramp sensors, to assess potential changes in traffic entering or exiting the freeway at individual interchanges along the corridor.

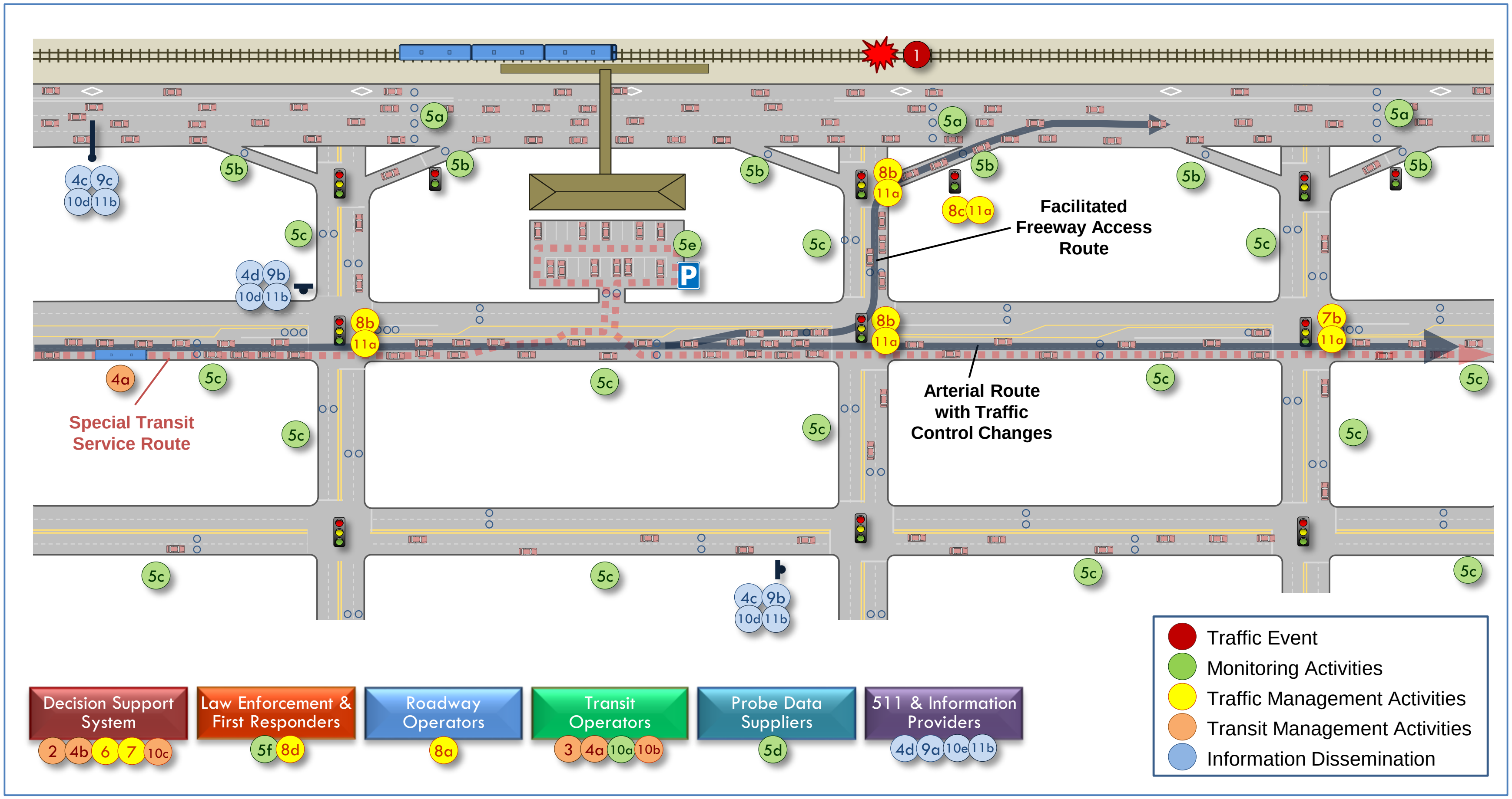

Figure 14-12 – Major Transit Incident: Response Elements

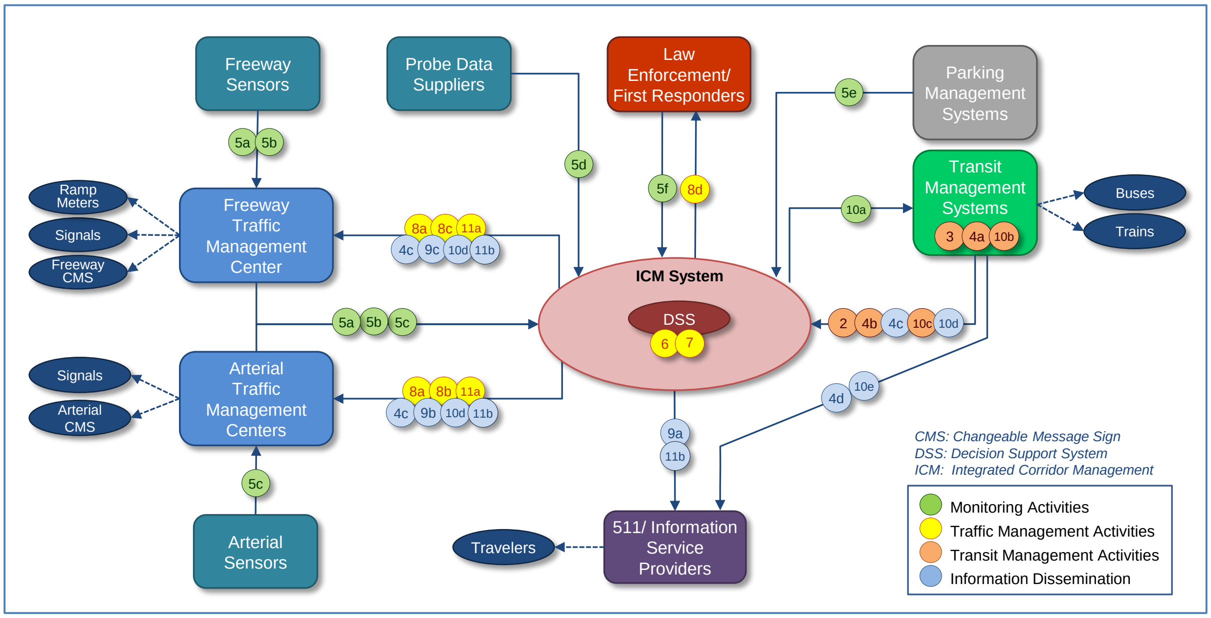

Figure 14-13 – Major Transit Incident: Information Flow

c. Arterial traffic sensors, to assess potential changes in arterial traffic.

d. Probe vehicle data collected from various sources, to assess changes in travel speed along freeway and arterial roadway segments, as well as shifts in traveled routes.

e. Parking occupancy data, to assess the availability of parking at park-and-ride lots that may be used to support the implemented transit response plan.

f. Incident reports from CHP and local law enforcement and first responding agencies.

6. **Traffic impact assessment** – Every 15 minutes, the ICM system instructs the DSS to predict how traffic conditions in the corridor would evolve over the next hour under the observed traffic demand if all existing traffic management strategies were kept in place. This becomes the basis for evaluating potential alternate response plan.

7. **Traffic response planning** – – If the collected data or simulation results indicate that corridor operations are significantly affected by travel demand or traffic patterns changes induced by the incident, when compared to normal-day operations, the DSS initiates the development of a response plan to address the situation. This process starts with an assessment of traffic management devices that could participate in the response. Business rules agreed upon by all corridor stakeholders are then used to develop several candidate response plans considering both traffic and transit needs. This process takes into account all active local constraints, such as school zones, low traffic areas, etc. The operational efficiency of each candidate response plan is subsequently evaluated using simulation or other analytical methods, and the plan resulting in the best overall performance for the corridor is recommended for implementation.

8. **Implementation of traffic management plan** – Based on the response plan recommended by the DSS, control action requests are sent by the ICM system to the agencies controlling the traffic

management assets targeted by the selected plan. For the current scenario, this may imply the following control actions:

a. Approval of the requested change by individual roadway operators, if required.

b. Implementing pre-approved signal timing plans providing added traffic carrying capacity in the main direction of traffic at Caltrans-, county-, and/or city-controlled intersections along arterials observed to carrying higher than usual traffic flows. Whether the changes affect one or multiple arterials depends on the magnitude of the observed deviation in traffic patterns relative to a normal day and the business rules used to identify routes to be used in the traffic management plan.

c. If needed, increasing the rate at which vehicles are allowed to enter the freeway at select on-ramps to help relieve congestion on nearby arterials.

d. If relevant, informing local law enforcement and/or the CHP of the traffic management plan that has been recommended by the ICM system and approved by traffic managers.

9. **Dissemination of preferred arterial routes** – If deemed relevant to help address unusual congestion that has developed on arterials because of the transit incident, additional information is disseminated to inform freeway and arterial motorists of the recommended arterial route to take if traveling off the freeway.

    a. Information regarding the recommended arterial routes is pushed out to the regional 511 system and interested information service providers.

    b. Available arterial CMSs, dynamic trailblazer signs, and/or static signs are used to inform motorists on the arterials of the recommended route to get back to the freeway.

    c. Messages informing freeway motorists of a recommended exit and/or arterial to take if existing the freeway are posted by Caltrans on select CMSs along the freeway.

10. **Additional transit service adjustments –** After having implemented the developed transit response plan, transit dispatchers from the affected agency keep track of travel conditions in the corridor and periodically reassess whether the implemented temporary service should be tweaked. The following activities may be conducted by transit dispatchers and the ICM system for managing potential service changes:

    a. Periodically, transit dispatchers connect to the ICM system to assess how local traffic is impacted by the transit incident. They also review operational data from buses and light-rail trains in service to assess the magnitude of any major service deviation compared to the initial transit response plan.

    b. Based on their expert judgment, and possibly recommendations from the DSS, transit dispatchers decide to implement temporary service adjustments.

    c. Transit dispatchers communicate service changes to relevant vehicle operators and input them into the DSS to allow the changes to be considered in future corridor evaluations.

    d. If relevant, requests are entered into the ICM system to post messages on arterial and/or freeway CMSs to inform the traveling public of the transit service changes.

e. If relevant, transit operators push messages about the transit service changes directly to the regional 511 system and relevant information providers.

11. **Return to normal operation** – After an initial response plan has been implemented, the ICM system keeps tracking travel conditions in the corridor and periodically adjusts the implemented traffic management plan if needed. After the incident is cleared, traffic sensors on the freeway and arterials will pick up a gradual return to normal traffic conditions. Once certain traffic flow or delay thresholds are crossed, the ICM system will:

    a. Send instructions to return to normal operation to the various traffic management assets that have been used in the implementation of the recommended response plan.

    b. Disseminate updated travel information to 511 systems and information providers.

Table 14-6 describes the key roles and responsibilities of individual stakeholders for this scenario.

Table 14-6 – Roles and Responsibilities: Transit Incident

Agency/Entity	Roles and Responsibilities
Caltrans	• Assess traffic conditions on freeway • Supply information to ICM system • Adjust ramp meters at selected freeway on-ramps and connectors • Adjust traffic signal operations at intersections under their jurisdiction (mostly freeway ramp signals) • Post incident-related messages on freeway CMSs
Local cities	• Assess traffic condition on arterials under their jurisdiction • Supply information to ICM system • Adjust traffic signal operations at intersections under their jurisdictions • Post incident-related messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs
LA County	• Assess traffic conditions on arterials under its jurisdiction • Supply information to ICM system • Adjust traffic signals operations at intersections under its jurisdiction • Post incident-related messages on available arterial CMSs • Post route guidance information on available dynamic trailblazer signs • Operate the Information Exchange Network (IEN)
Transit agencies	• Assess transit operations in the corridor • Assess parking availability at park-and-ride lots (where available) • Supply information to ICM system • Develop transit response plan
California Highway Patrol	• If necessary, undertake actions to help ensure traffic safety on the freeway and freeway ramps
Local law enforcement	• If necessary, undertake actions to ensure traffic safety on the arterials
Information Service Providers	• Supply probe vehicle data to the ICM system • Disseminate information to motorists via travel information applications, radio, or other media

15. SUMMARY OF IMPACTS

This section summarizes the potential impacts of the proposed ICM system on how the various transportation systems and services within the I-210 corridor are operated and managed by their respective agencies. Elements presented in this section include:

- Summary of improvements sought
- Summary of required enhancements
- Anticipated benefits
- Operational impacts
- Organizational impacts
- Potential limitations and disadvantages
- Metrics for assessing system operations

15.1. SUMMARY OF IMPROVEMENTS SOUGHT

Key improvements sought in how the I-210 corridor is operated and managed include:

- **Enhance communication capabilities with field devices**
  - Provide fast, reliable communication lines with field devices
  - Enable real-time or near-real-time communication with relevant field devices

- **Expand traffic and travel monitoring capabilities**
  - Improve the capability of providing traffic volumes and turning counts
  - Increase the ability to monitor travel times between specific locations
  - Enable traffic and travel monitoring systems to provide data in real time
  - Increase the ability to track vehicle routing patterns
  - Increase the ability to visually assess conditions on managed roadways and systems
  - Produce performance-based metrics supporting various operational and reporting needs

- **Improve the ability to respond quickly to changes in travel demand, congestion, or operating conditions**
  - Provide tools allowing system operators to quickly assess the potential operational impacts of the control and management strategies being considered
  - Enable all relevant traffic management devices to be centrally controlled from the associated TMCs
  - Improve communication between the various transportation management centers operating in the corridor
  - Improve communication between transportation management centers and transit operation centers managing services within the corridor

- **Provide system managers with integrated, multi-system decision-support tools**
  - Develop integrated processes for gathering, validating, analyzing, and distributing data

  - Implement standardized system interfaces and data communication protocols
  - Develop integrated tools for planning, design, and evaluation
  - Develop optimization tools considering the needs and capabilities of all transportation elements and system users within a corridor
  - Develop interagency agreements promoting integrated operations and management

- **Improve coordination among transportation systems**
  - Increase data sharing capabilities among agencies operating within a corridor
  - Enhance coordination between freeway and arterial traffic management operations
  - Enhance coordination between roadway and transit operators
  - Enhance coordination operations among transit agencies
  - Enhance coordination among law enforcement agencies, first responders, freeway operators, and arterial operators during incidents

- **Improve the dissemination of real-time travel information to motorists, transit riders, and other travelers**
  - Provide comprehensive incident/event information to corridor travelers
  - Improve information dissemination to en-route travelers, particularly hands-free delivery capabilities to motorists
  - Provide reliable travel time forecasts based on current and projected transportation system conditions
  - Provide real-time parking availability at park-and-ride facilities to travelers

- **Improve the ability to proactively influence travel demand and promote route, mode, and/or time-of-day shifts**
  - Improve the ability to communicate en-route information to travelers
  - Provide effective dynamic route guidance around problem areas in response to incidents, planned events, or unusual situations
  - Improve the ability for travelers to obtain and compare information about trips based on various alternative transportation modes
  - Improve the ability for traffic managers to influence travel mode and itinerary choices through targeted traffic control actions and information dissemination

The end goal is to develop a corridor-based transportation management system providing:

- Enhanced real-time control capabilities
- Reliable information about current and projected travel conditions within the corridor
- Performance-based metrics supporting operations and reporting needs
- Coordinated operations across various transportation systems and modes
- Improved corridor-wide travel performance within individual and across multiple modes
- Greater partnership opportunities between regional transportation agencies, local agencies, and private sector entities

15.2. SUMMARY OF REQUIRED ENHANCEMENTS

To implement the proposed I-210 Pilot ICM system, various ITS systems, components, and infrastructure must be in place. The following lists the identified enhancements to existing systems that are required, or highly desired, to support the operation of the proposed ICM system:

- **Traffic monitoring**
  - Maintenance of high health status for existing mainline, HOV lane, on-ramp, off-ramp, and connector traffic detectors along the sections of interest of I-210, SR-134, and I-605
  - Ability to collect turning counts at key arterial intersections
  - Ability to retrieve in real time traffic counts and signal control status data from all signalized intersections along managed arterials
  - Ability to monitor travel times beyond the two areas in Pasadena and Arcadia where travel times are already monitored
  - Integration of probe vehicle data into the corridor traffic evaluation processes
  - Ability to collect incident reports generated by law enforcement agencies
  - Ability to track planned lane closures from each agency
  - Link to weather monitoring stations
  - Algorithms capable of assessing traffic conditions (volume, speed, density, delays, etc.) and travel patterns along arterials and freeway segments based on available information
  - Algorithms capable of identifying whether an incident may be affecting corridor operations
- **Transit monitoring**
  - Ability to retrieve relevant static data, such as routes and schedules, from transit agency servers
  - Ability to retrieve relevant live operational data from CAD/AVL systems, such as significant service delays
  - Algorithms capable of flagging service deviations
- **Parking monitoring**
  - Ability to retrieve parking occupancy data from all park-and-ride facilities to be included in the operation of the ICM system
- **Traffic control devices**
  - Ability to communicate from a central location to all signal controllers along managed arterials, freeway on-ramps, and freeway-to-freeway connectors
  - Ability for signal controllers to hold multiple signal timing plans, or alternatively to receive new plans from a central location
  - Development of signal timing plans optimized for handling incident/event traffic
  - Interfaces capable of translating control actions from the ICM system into actionable commands by field devices connected to each traffic control system
- **Traveler information systems**
  - Ability to send relevant information to the regional 511 system and information systems operated by third-party providers, including mobile applications

  - Ability to disseminate information along freeways and arterials to allow suitable route guidance to be provided to motorists during incidents and events
  - Algorithms capable of recommending messages to be displayed on CMS or arterial dynamic trailblazer signs
  - Method for providing parking occupancy information to motorists

- **Communication systems**
  - Communication links with sufficient bandwidth between field devices and traffic management centers / transit operations center to support anticipated real-time data collection needs
  - Communication links with sufficient bandwidth between the ICM servers and local traffic management /transit operations centers to support anticipated center-to-center data exchanges
  - Ability for roadway operators, transit dispatchers, law enforcement officers, and other relevant entities to access the ICM system
  - Enhancement to regional communication networks to support data communication needs (if selected for use by the ICM system)
  - Methods for performing network health monitoring and identifying potential issues

- **Interagency collaboration**
  - Cooperative agreements
  - Development of joint operational procedures

- **ICM system**
  - Systems and software to acquire real-time data streams from connected systems
  - Software to develop operational evaluation scenarios and conduct evaluations
  - Software and methods to produce corridor-optimized response plans to identified incidents and events
  - Software to initiate automated response plan implementation when allowed

- **Data archive**
  - Software and methods to collect, aggregate, categorize, and store received data
  - Software and methods necessary to access archived data to provide to other systems

15.3. ANTICIPATED BENEFITS

The I-210 Pilot ICM concept provides beneficial strategies that enhance how the I-210 corridor is currently operated and managed. The following are the benefits that the system is expected to provide:

- **New decision-making tools –** The ICM system will expand the number of tools that TMC operators, traffic managers, and transit dispatchers may use for incident response. In addition to having access to arterial, ramp, and freeway traffic data, operators will have access to a decision support system capable of evaluating corridor operations under alternate control strategies and producing recommended courses of actions to address the identified incidents or events.

- **Implementation of performance-based corridor-wide strategies –** The ICM system will evaluate candidate response plans and provide recommendations using metrics attempting to capture the efficiency of travel within the corridor.
- **Enhanced coordination of activities between Caltrans, local traffic management agencies, transit agencies, and first responders** – The need to collect operational information across transportation systems and modes and to develop cross-jurisdictional strategies to maximize the operational efficiency of the corridor will promote the development of dialogues across agencies on how to operate the corridor during incidents and events.
- **Complementary multi-jurisdiction, multi-modal forum for addressing corridor issues** – By promoting collaboration between agencies and coordination of activities across systems and modes, the ICM system will promote the development of a multi-jurisdictional framework to address corridor operational problems from a multi-modal, corridor-wide perspective.
- **Reduced decision times to respond to incidents** – Through enhanced monitoring systems and its corridor evaluations, the ICM system should be able to detect earlier the congestion that may developing from incidents and events and start planning at an earlier time mitigating actions to maintain desired corridor mobility.
- **Reduced impacts of incidents and events on corridor mobility –** The system will provide travelers with incident notifications, route recommendations, and mode shift suggestions to reduce the impacts of incidents on their travel time. Adjustments to traffic signal and ramp metering operations will further be implemented to meet the altered traffic demand created by the incidents and increased delays.
- **Improved safety along freeway, freeway ramps, and arterials –** A more coordinated and organized approach when rerouting traffic around incidents will reduce risks of secondary collisions caused by unexpected congestion or motorists who are uncertain about where to go.
- **Improved transit service during incidents and events** – Through the ability to monitor travel conditions within the corridor and access information about recommended control responses, transit dispatchers will be able to better plan detours around incidents or adjust transit service offerings to meet anticipated demand. This may potentially include the ability to receive detour suggestions from the ICM system.
- **Increased attractiveness of transit services** – By providing motorists with relevant information about transit services, such as comparative transit travel times, the proposed system may increase the attractiveness of transit services offered within the corridor and entice some motorists to switch travel model to reach their destination during incidents or events (if sufficient parking and/or transit capacity is available).
- **Enhanced traveler information** – The development of real-time monitoring systems and include of new data sources will allow enhanced information about travel conditions within the corridor to be provided to travelers.
- **Improved traveler experience –** Travelers are the ultimate end users of the system. By reducing the impacts of incidents and event traffic, the system will improve travel time, or at least reduce travel time variability, along the corridor.
- **Reduction of safety hazard caused by freeway on-ramp/off-ramp queue overflows –** When responding to incidents or events, the system will monitor whether freeway on-ramp and off-

ramps are overflowing, or threatening to overflow, because of the changing traffic patterns. If overflowing is detected or projected to occur, the system will send recommended changes to the metering rate at one or multiple on-ramps and/or traffic signals controlling traffic at the end of one or multiple off-ramps to reduce overflowing risks. This would translate into the reduction of safety hazards on arterials or freeway mainline created by overflowing ramp queues.

- **Potential improvements in air quality** – By developing traffic management plans attempting to maintain mobility during incidents and events, and promoting the utilization of transit where relevant, the proposed system offers the potential to reduce vehicle emissions and improve air quality along the corridor.
- **Promotion of future ICM system enhancements or deployments** – By demonstrating how multi-jurisdictional, multi-modal coordinated operations could enhance mobility in a typical urban corridor, the proposed system would demonstrate the validity of investments in ICM systems and potentially help justify further development or secure additional funding.

15.4. OPERATIONAL IMPACTS

The follow lists several impacts on how transportation systems within the I-210 corridor would be operated following the implementation of the proposed I-210 Pilot ICM:

- **Enabling corridor-based performance decision-making** – Instead of making operational decisions strictly based on how decisions would affect individual systems, individual agencies will be able to make management decisions based upon how overall corridor operations might be affected by the decisions being considered. This means potentially allowing specific roadways not to be operated at an optimal level if this results in better overall corridor mobility.
- **Increased inter-agency communications** – During incidents and events, Caltrans staff may need to contact individuals from other local agencies, and vice versa, to verify elements of a proposed response plan, or to discuss implementation issues. Communication may also be established with CHP and local first responders, as well as with transit system operators, to improve incident response and management. When not managing incidents, staff from various agencies may also need to discuss periodically inter-jurisdictional issues regarding system operations. Depending on the case, this may require developing new procedures identifying whom to contact and how for a given situation.
- **Additional operator responsibilities** – Deployment of the ICM system will require some involvement from each of the participating operators. Following system launch, operators will need to pay attention to control recommendations developed by the ICM system. Depending on system setup, and the specificity of the situation, this may involve reviewing recommended actions and entering commands into the targeted control systems. Roadway operators may also be asked to enter into the ICM system information about planned road closures, changes to signal control plans, etc., while transit dispatchers may be asked to enter notable service deviations on routes servicing the I-210 corridor. Operators will further be required to provide feedback on recommendations and system operations.
- **Increased reliance on traffic data streams** – Operation of the ICM system will require continuous monitoring of traffic flows and speeds on the freeway mainline, on-ramps, off-ramps, freeway-to-freeway connectors, and arterials.

- **Access to new traffic data sources** – In addition to relying on traffic data provided by traditional loop detectors and video systems, the ICM system will seek to integrate travel time information provided local technologies and/or third-party probe data collection systems. Information provided by transit automatic vehicle location systems may also be used.
- **Increased demand for incident verification and monitoring** – Response plans will only be developed after an incident or event has been verified. While traffic managers from Caltrans and local agencies are already accustomed to verify incidents occurring on their network before determining what to do, the ICM system may create a need to verify incidents occurring on "other" networks to understand the recommendations produced by the ICM system. Ideally, such verification could be entered into the ICM system by the agency managing the roadway segment on which the incident occurred.
- **Increased demand for real-time communication** – To avoid delaying responses to incidents and events, information must be supplied without excessive delay to the ICM system. Efficient and reliable communications will be needed to collect and monitor traffic data, view CCTV video images, provide incident information to traveling public, and issue response plans. This creates a need for real-time communication from field devices to management or operations centers, as well as from center to center.
- **Increased efficiency of traffic signal and ramp meters** – Traffic and travel demand management provided by the ICM system will aim to improve the operational effectiveness of traffic signals and ramp meters by distributing demand to areas where capacity is available. A successful ICM system will allow traffic to be dynamically rerouted according to current and projected capacity restrictions caused by incidents or other control policies.
- **Improved capability to proactively influence travel patterns** – The ability to evaluate near-future corridor operations under alternative control strategies, ability to control devices in real-time, and availability of additional information dissemination tools will allow transportation system managers to better anticipate operational needs, to implement earlier management strategies needed to address the identified needs, and to better direct travelers within the corridor.
- **Updated guidelines for freeway CMS messaging** – Caltrans District 7 currently post messages on freeway CMS using appropriate protocols and approved CMS Statewide Guidelines. Generally specific detour information is not called out, especially when freeway lanes are still available. In most cases, current wording only goes as far as indicating "Use Alternate Route". Guidelines may need to be developed to determine how to provide specific detour information.
- **Added maintenance requirements** – The reliance on real-time monitoring and control will increase the need to keep operational the devices providing information to the ICM system or that may be used to implement recommended responses plans. This includes ensuring a high operational heath status for connected traffic detectors, transit monitoring systems, parking management systems, and roadside information devices. It also includes prioritizing maintenance needs to ensure that the most critical system elements are typically repaired first.
- **New training requirements** – Maintenance personnel may require additional training in order to support new detection systems, ramp-metering systems, or traffic signal systems. TMC operators may also require additional training to help them understand the operation of the ICM system and implement recommended response plans.

15.5. ORGANIZATIONAL IMPACTS

The following are the potential organizational impacts that may arise from the deployment of the proposed I-210 Pilot ICM system:

- **Participation in ICM system committees** – Successful system operations will require participating agencies to attend scheduled meetings to discuss system operation and maintenance needs. This will include delegating individuals to participate in the activities of the Technical and Operations Advisory Committee, and, if needed, the Connected Corridors Steering Committee.
- **Closer collaboration between stakeholders** – The operation, and maintenance of the proposed ICM system will require close collaboration between roadway operators, first-responding agencies, transit system operators, and information service providers.
- **Increased data sharing among agencies** – Adequate system operations will require agencies to share relevant data among them. Data sharing may further require the adoption of standardized data formats and communication protocols across agencies facilitating data transfer across management and operation centers. Agreements may also need to be reached on suitable bandwidth requirements for data communication links.
- **Additional maintenance personnel needs** – Depending on existing staffing levels, the need to operate and maintain additional equipment may translate into additional personnel needs for individual agencies.
- **Adjustment of agency responsibilities** – Depending on the operational needs of the ICM system, individual agencies may be assigned new responsibilities.
- **Administrative reorganizations** – Depending on needs, some agencies may implement administrative reorganizations to facilitate corridor management decisions or ICM system operations. An example is the internal reorganization currently being considered by Caltrans District 7 that should result in the appointment of dedicated Corridor Managers and substantial changes in how various tasks are divided among various divisions and offices.

15.6. POTENTIAL LIMITATIONS AND DISADVANTAGES

The following lists potential factors that may limit the effectiveness of the proposed ICM system:

- **Unclear detour recommendations** – While it can be assumed that a significant portion of travelers within the corridor may be regular commuters with some knowledge of the local road network, it cannot be assumed that all travelers know exactly where each arterial is located. Disseminated information must therefore be clear enough to guide travelers through a detour and allow them to find their way back onto their original road, whether this is the I-210 or a local arterial.
- **Traveler willingness to comply with routing recommendation** – The effectiveness of the proposed system rests upon the willingness of travelers to comply with the routing recommendations being disseminated during incidents. Due to personal reasons, some travelers may choose to ignore the recommended detours. Others may also inadvertently miss information posted on CMS or trailblazer signs, or directions provided by a mobile navigation application. While a small proportion of travelers electing to follow their own path through the corridor may

have a minimal impact on system performance, a significant proportion ignoring the disseminated routing recommendation may significant reduce potential system benefits.

- **Navigation applications ignoring ICM recommendations** – Third-party navigation applications not factoring the recommendations developed by the ICM system may be entice travelers to make routing decisions that are in opposition to what the ICM system seeks to achieve.
- **Technical feasibility of needed data processing and response mechanisms** – Development of system capabilities may be limited by the technology currently available. Implementation of some system functionalities may thus be affected by the need to develop new software or unique network or system architectures.
- **Provision of dubious, low-quality data** – The quality of the response plans generated by the ICM system will depend heavily on the quality of the data provided to it. While the system should be able to tolerate small quantities of bad data, the reception of significant volumes of bad data may lead to inaccurate representations of corridor operations, and the development of response plans that could worsen corridor operations during incidents.
- **Accuracy of incident location –** The provision if inaccurate incident location may lead the ICM system to predict incorrectly the impacts from the incident and to develop response plans not suited for the incident.

The following further lists some potential perceived drawbacks associated with the deployment and operation of the proposed I-210 Pilot ICM system:

- **Increased system monitoring and maintenance requirements** – To provide suitable situational awareness and response mechanisms, individual agencies may be required to deploy and operate additional equipment, thus creating additional maintenance needs for agency staff.
- **Increased funding requirements** – The need to operate and maintain additional equipment will likely translate into additional funding needs for each agency.
- **Potential confusion with police and fire** – Response plans recommended by the ICM system may diverge from what first-responding officers typically do to manage incidents, thus leading them to ignore the recommendations. While this may occurs, proper engagement of first responders in system operations should reduce confusion on what the best courses of action may be.

15.7. METRICS FOR ASSESSING SYSTEM OPERATIONS

The ability of the ICM system to produce corridor improvements satisfying all stakeholders will depend on the metrics used for assessing corridor operations. The selection of such metrics is a somewhat complex problem, as different metrics are often used to manage freeways, arterial networks, transit systems, urban mobility, and environmental impacts. As an example, Table 15-1 lists metrics commonly used to evaluate specific operational dimensions of freeways, arterials, transit, and parking systems.

Ideally, a limited set of metrics should be used to evaluate corridor operations. This will not only simplify data processing needs, but also facilitate the understanding of the decisions made by the ICM system. In this perspective, based on corridor stakeholder input and experiences from other ICM systems, the following base metrics are suggested for evaluating corridor performance:

Table 15-1 – Potential Corridor Metrics

Category	Metric	Freeway Operations	Arterial Operations	Transit Operations	Parking Operations
Mobility	Average travel Time	●	●	●	
	Average travel speed	●	●	●	
	Vehicle-hours of delay (VHD)	●	●	●	
	Person-hours of delay (PHD)	○	○	●	
	Average delay per vehicle	●	●	●	
	Average delay per person	○	○	●	
	Congested lane-miles	●	○		
	Level of Service (LOS)	●	●		
Productivity	Vehicle flow	●	●	○	
	Vehicle-miles traveled (VMT)	●	●	●	
	Vehicle-hours of travel (VHT)	●	●	●	
	Person flow	○	○	●	
	Person-miles traveled (PMT)	○	○	●	
	Person-hours of travel (PHT)	○	○	●	
	Flow density	●	○		
	Queue Length	●	●		
	Saturation flow rate	○	●		
	Vehicle flow capacity	●	●	○	
	Person flow capacity	○	○	●	
	Volume-to-capacity Ratio	○	●		
	Number of transit boarding/alighting			●	
	Parking availability				●
	Parking utilization rate				●
Reliability	Travel time index	●	●	●	
	Buffer index	●	●	●	
	Mean travel time	●	●	●	
	Median travel time	●	●	●	
	Nth percentile travel time	●	●	●	
	On-time performance			●	
Safety	Number of accidents	●	●	●	○
	Number of accidents with fatalities	●	●	●	○
	Number of accidents with injuries	●	●	●	○
	Frequency of accidents (per time period)	●	●	●	○
	Frequency of accidents with fatalities	●	●	●	○
	Frequency of accidents with injuries	●	●	●	○
	Rate of accidents (per million VMT)	●	●	●	○
	Rate of accidents with fatalities	●	●	●	○
	Rate of accidents with injuries	●	●	●	○
Environment	Fuel consumption per vehicle	●	●	●	
	Fuel consumption per person	○	○	●	
	Emissions per vehicle	●	●	●	
	Emissions per person	○	○	●	

● Measure of primary interest ○ Measure of secondary interest

- **Change in person-miles traveled** (both on a nominal and percentage basis), to measure change in overall travel demand placed on the corridor when considering both roadways and transit services
- **Change in person-hours of delay** (both on a nominal and percentage basis), to measure improvement in corridor mobility
- **Change in travel time reliability**, to measure potential reduction in uncertainties associated with highly variable traffic conditions
- **Reduction in the number and severity of secondary collisions** (both on a nominal and percentage basis), to measure the safety benefits of the implemented corridor management strategies

As indicated, using person-based metrics allows considering both increase/reduction in motorized traffic and increase/decrease in transit ridership, thus overall changes in travel demand. However, a potential problem with the use of person-based metrics is to know how many individuals are present in each vehicle. While information about the number of occupants in each vehicle is typically unavailable, average values may be used for passenger cars and for transit operations based on historical data from relevant occupancy surveys. While using such values would not allow developing an *exact* operational assessment, no existing technology currently allows such an assessment to be made. While imperfect, using average vehicle occupancy thus provide a practical approach to consider the relative carrying capacity of passenger cars and transit vehicles in the current evaluation context. Vehicle-based evaluations would nevertheless remain possible by attributing the same occupancy value (i.e., a value of 1) to all vehicle types.

Whether additional metrics should be used, and how these metrics should be combined to determine recommended response plans, will be determined collectively by corridor stakeholders during the design phase of the ICM system.

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APPENDIX A: LIST OF ACRONYMS

ADT	Average Daily Traffic
APC	Automated Passenger Counter
APID	All-Purpose Incident Detection
ATMS	Advanced Traffic Management System
AVL	Automated Vehicle Location
CAD	Computer-Aided Dispatch
Caltrans	California Department of Transportation
CCTV	Closed-Circuit Television
CDI	Command/Data Interface
CHP	California Highway Patrol
CMS	Changeable Message Sign
CSMP	Corridor System Management Plan
CSTAN	Countywide Strategic Truck Arterial Network
DSS	Decision Support System
FSP	Freeway Service Patrol
GPS	Global Positional System
HAR	Highway Advisory Radio
HICOMP	Highway Congestion Monitoring Program
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
ICM	Integrated Corridor Management
IDL	Interface Definition Language
IEN	Information Exchange Network
ITE	Institute of Transportation Engineers
IVR	Interactive Voice Response
KITS	Kimley-Horn Integrated Transportation System
LA DOT	City of Los Angeles Department of Transportation
LA SAFE	Los Angeles County Service Authority for Freeway Emergencies
LACDPW	Los Angeles County Department of Public Works
LACTMC	Los Angeles County Traffic Management Center
LACO	Los Angeles County
LARTMC	Los Angeles Regional Transportation Management Center
LCS	Lane Closure System
LMR	Local Mainline Responsive Metering
Metro	Los Angeles County Metropolitan Transportation Authority
PATH	Partners for Advanced Transportation Technology
PeMS	Performance Measurement System
PM	Post Mile
RIITS	Regional Integration of Intelligent Transportation Systems
SCAG	Southern California Association of Governments
SCATS	Sydney Coordinated Adaptive Traffic System
SR	State Route
SWARM	System-Wide Adaptive Ramp Meter
TASAS	Traffic Accident Surveillance and Analysis System

TMC	Traffic Management Center
TMDD	Traffic Management Data Dictionary
TMT	Traffic Management Team
TOD	Time of Day
TSP	Transit Signal Priority
TSSP	Traffic Signal Synchronization Program
VMT	Vehicle-Miles Traveled
VPN	Virtual Public Network
XML	Extensible Markup Language