VII California
Concept of Operations

A Collaboration between the Metropolitan Transportation Commission (MTC), Caltrans, BMW North America, DaimlerChrysler RTNA, Toyota InfoTechnology Center, and Volkswagen of America ERL

University of California Partners for Advanced Transit and Highways (PATH) and Telvent Farradyne, Consultants

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VII California Concept of Operations

This document describes the Concept of Operations (ConOps) for *VII California* in eight parts:

1. Goals
2. Use Cases
3. Architecture
4. Vehicle-Roadside Component
5. Roadside Component
6. Roadside-Center(s) Component
7. Processing and Archiving
8. Evaluation Plan

It is written at high level and is a part of an iterative process where multiple stakeholders – developers and users alike – can describe expectations of the target *VII California* system in terms that need not be quantifiable and testable. This document will be used as input to the development of *VII California* requirements, then specifications.

The *VII California* testbed and proof of concept development is a joint Metropolitan Transportation Commission (MTC), Caltrans, BMW North America, DaimlerChrysler RTNA, Toyota InfoTechnology Center, and Volkswagen of America ERL activity. Multiple collaborating partners are further sought as co-developers and, ultimately, "owners." In the current work, California PATH is working with Caltrans on the infrastructure (roadside unit) implementation and vehicle-infrastructure messaging and communication of the VII data, whereas Telvent Farradyne is working with MTC on backhaul communications and collection, processing and archiving of data at the center.

1.0 Goals

The ultimate goals of the *VII California* program are to:

- Better manage the safety and productivity of the surface transportation system;
- Combine the resources, expertise, and innovations of the public sector, the auto industry, aftermarket suppliers, and other private sector participants for the benefit of the traveling public;
- Build upon California's already considerable existing infrastructure investments; and
- Create opportunities for innovation in the transportation system, exploring commercial uses of the system to fund its deployment and operation.

Beginning in 2005, the *VII California* partners set out to achieve these goals and embarked upon the development of a testbed to understand the technical feasibility and institutional value of VII. The near-term goals for this testbed are to:

- Inform future decisions for the National VII Program – specifically the 2008 deployment decision;
- Inform future decisions for California and Bay Area System Management Programs; and
- Assess real-world implementations of VII infrastructure, architecture and operations.

The development period of *VII California* is currently running through 2008, over which time both the overarching goals and the testbed goals will be realized. The *VII California* Working Group is developing the testbed in two phases: World Congress Demonstration and VII Proof of Concept. Specific tasks and durations within these phases are provided in the timeline given in Figure 1-1.

Phase/Task	2005				2006				2007				2008			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Phase 1: World Congress Demonstration																
Design, Build and Install WC Demo	■	■	■													
Operate WC Demo				■	■	■										
Evaluate WC Demo					■	■										
Phase 2: Proof of Concept																
Design, Build and Install VII Proof of Concept							■	■	■	■	■	■	■			
Operate VII Proof of Concept									■	■	■	■	■	■	■	■
Evaluate VII Proof of Concept											■	■	■	■	■	■

Figure 1-1. ***VII California High-Level Schedule***

The first milestone for *VII California* was to participate in the 2005 ITS World Congress. After this first milestone was successfully accomplished, the *VII California* partners established a second milestone to provide up to 40 roadside equipment (RSE) locations along Caltrans-operated routes in the San Francisco peninsula, at or near Palo Alto: US-101, US-280 and El Camino Real (SR 82), shown in Figure 1-2. The *VII California* Program is currently in the process of trying to achieve this second milestone. The objectives of these early *VII California* activities are to:

- Demonstrate and outreach emerging *VII California* testbed: give notice that Caltrans, MTC and partners are committed to the concept and will objectively investigate its potential;
- Gain experience in VII and use case development and deployment; and
- Develop and promote the *VII California* public-private partnership.

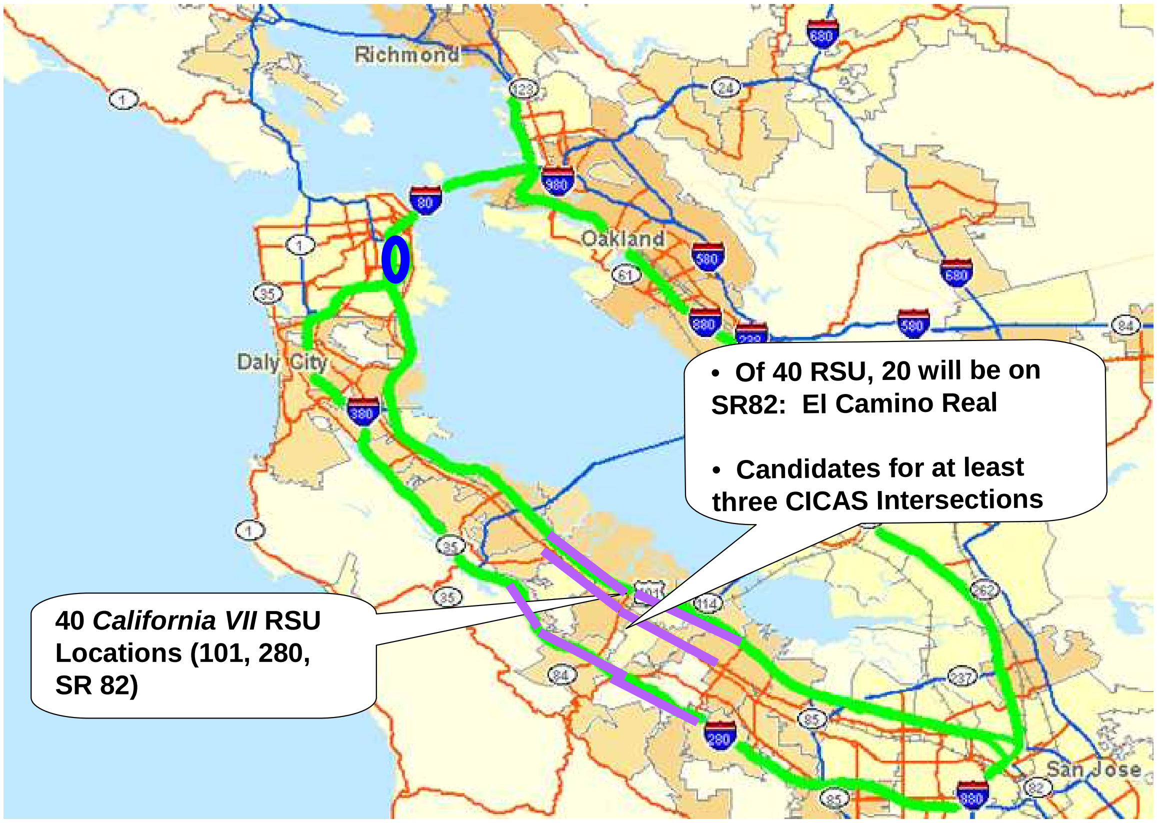

Figure 1-2. Potential RSE Locations

To further support the VII California Program goals, Caltrans and MTC have recently issued a Call for Submissions (CFS) to solicit the participation of private sector partners to invest in and cooperate with the *VII California* Program to create a testbed environment in the Bay Area for VII field testing and evaluation. Caltrans and MTC hope that the public-private partnerships spawned by the CFS will help increase the size and scope of the testbed. This expanded testbed and these new business relationships are needed in order to develop knowledge about VII technical and business model issues that will be vital to inform both state and national decisions about VII viability.

It is understood that the *VII California* goals may be revisited and revised during the course of the *VII California* demonstration period.

2.0 Use Cases[1]

In November of 2005, at the Intelligent Transportation Systems (ITS) World Congress held in San Francisco, a technology demonstration called the Innovative Mobility Showcase (IMS) was conducted. It involved numerous public and private sector

[1] Obtained from pp. 6 – 8 of *VII California Development and Deployment* program plan.

participants including VII California. Based on this experience, Caltrans and MTC have identified the following public sector VII use cases as being of priority interest for proof of concept testing:

1. **Traveler Information –** Traveler information systems provide information that may be relevant to the performance of a traveler's trip, including travel times, incident alerts, road closures, school and work zones and weather conditions. This application involves both collecting probe data from the vehicles and sending traveler information to the vehicle's On-Board Equipment (OBE). The OBE shall send raw location, time, speed and direction information of the vehicle to Roadside Equipment (RSE), which passes the data along to a central processing center where it is used to create timely and accurate real-time traveler information. Travel times will be provided on a regular recurring basis, and referenced either from landmark to landmark, or between geo-located road positions. Interpretation of travel time data will be left up to the vehicle system developers. Incident information and emergency notifications will use the same mechanisms as travel time notifications, except that these messages will be generated as soon as they are detected by the operations center. VII California's application will utilize MTC's 511 system to provide real travel times and incident information during proof of concept testing.
2. **Ramp Metering –** This application would enable more efficient freeway management by providing vehicle speed and spacing information to the RSE, allowing for dynamic, smooth on-ramp operation with minimal disruption to the mainline traffic flow. VII probe data will provide detailed vehicle snapshots, including timestamp, weather, vehicle position, speed, braking and acceleration information, as well as the vehicle's trajectory through the ramp and merge area(s) and the aggregated flow profiles of vehicles between ramps on a per-lane basis. From this data, other measures including link travel time and average ramp queue information can also be derived.
3. **Electronic Payment (Tolling) –** This application involves using VII onboard and roadside equipment in the electronic processing of bridge toll transactions.
4. **Intersection Safety –** This is the application of low latency, high availability, safety critical messaging between RSEs and OBEs for cooperative intersection safety, with focus on signal violation, dilemma zone warning (to address the onset of yellow signal phase) and reducing left-turn crashes. This family of applications may require high data rate, as wireless map updates may constitute a significant component of the message.

   An essential aspect of the Intersection Safety application is the VII California support of the Crash Avoidance Metrics Partnership (CAMP) Cooperative Intersection Collision Avoidance Systems – Violation

(CICAS-V) and DSRC components of the Caltrans-PATH CICAS-Signalized Left Turn Assistance (CICAS-SLTA) projects. (The CICAS projects are 80% funded by US DOT.)

5. **Curve Overspeed Warning** – Another application of low latency, high availability, safety critical messaging is curve overspeed warning, wherein road curvature (and potentially, road surface condition) would be broadcast by appropriately positioned RSEs to OBEs, and vehicles would combine this information with their dynamic state to provide in-vehicle warning to drivers, if necessary. An extension would be that vehicles that issue curve overspeed warnings would transmit such information to the roadside, enacting a general warning to unequipped vehicles.
6. **OEM Specific Applications –** This application includes an encrypted message set specific to Original Equipment Manufacturer (OEM) requirements, passed between vehicle, RSU and OEM center. The OEMs will use this message set for Customer Relation/Vehicle Diagnostic applications.

Caltrans and MTC are also supportive of using the testbed to conduct proof of concept tests for commercial applications that are developed and provided by individual automobile companies or other private sector organizations.

3.0 Architecture

The *VII California* architecture will be a framework that depicts how information needed to enable a variety of use cases will flow between vehicles and traffic management centers (TMCs), OEMs and other commercial locations, and how that information will be processed, stored and used for operational and evaluation purposes once it is received.

The *VII California* testbed architecture will evolve over time. Because California intends to be an early implementer of the national VII system, the ultimate architecture that supports actual operations will be the one adopted by the national VII Working Group. Version 1.1 of this national VII architecture was published in July, 2005 and will be the subject of continuing thorough review and discussion by public and private sector representatives, and testing and refinement leading to later versions, before adoption. More recently, USDOT has contracted with a team led by Booz Allen Hamilton to refine the National VII Architecture and to design and test a proposed VII network and related system components.

The *VII California* architecture will be an open architecture that will be designed to enable the testing of various technologies and subsystems, the integration of these technologies and subsystems, and various commercial and governmental applications. Key national activities, such as the development of prototype, standards-compliant DSRC roadside units by the DSRC Industry Consortium, various commercial wireless communications developments, and the implementation of backhaul communications technologies to meet VII requirements, will be closely monitored. The *VII California* architecture will be developed such that it can grow over time to accommodate these and other developments.

The initial architecture shown in Figure 3-1 is the one that was implemented for the 2005 World Congress. For expediency, a number of elements or features of Version 1.1 of the national VII architecture were not included in the initial architecture.

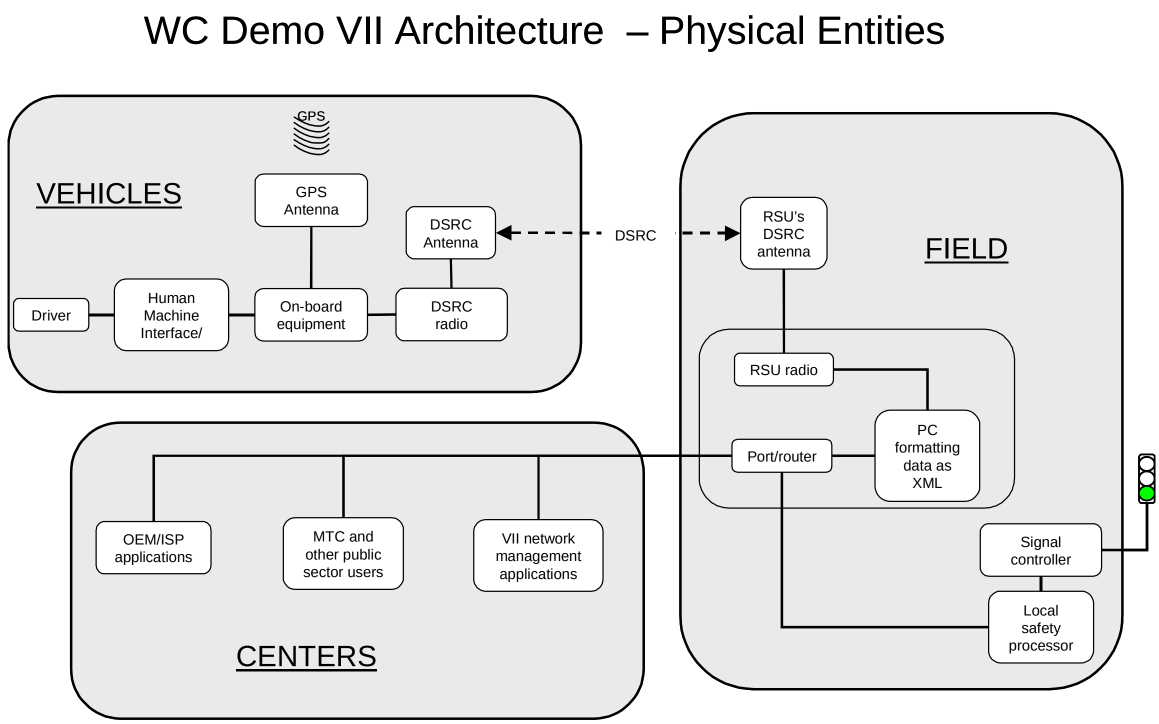

Figure 3-1. ***VII California*** **World Congress Demo Architecture**

As described more fully below, the initial *VII California* architecture enables the communication of data from equipment located on-board participating vehicles to roadside units deployed at selected locations. From there, the data is communicated to several locations, including the 511 Traveler Information Center (TIC), and to OEM processing centers, through a router and the appropriate addressing schemes. Data from the 511 TIC and the OEM locations is also communicated back to the roadside units, which transmits it to the participating vehicle on-board equipment, and then it is provided to the driver through audio or visual displays.

4.0 Vehicle-Roadside Component

4.1 Hardware

Development and installation of the onboard equipment (OBE) system and components are the responsibility of car company stakeholders. At this writing, the OBE system is notionally given, and further definition and correction as necessary will be included in subsequent iterations.

Per Figure 3-1, the vehicle has its onboard equipment suite, consisting of a driver, driver-vehicle interface, a suite of equipment comprising the OBE, and other VII positioning and communications components.

The vehicle positioning and time synchronization are done through an onboard global positioning system (GPS) unit, which includes a coaxial antenna connector. The positioning requirements from use cases, e.g., "WhichLane", may predicate whether companion roadside equipment is needed, e.g., local differential correction, Wide Area Augmentation System (WAAS) or use of High Accuracy National Differential GPS (HA-NDGPS).

For the OBE's, the basic communication system is a DSRC Wireless Access in Vehicle Environments (WAVE) radio, hereafter defined as a WAVE Radio Module (WRM).

To ensure compatibility with the OEM's test radios for the OBEs, Caltrans has purchased and will install 50 WRMs developed by the Crash Avoidance Metrics Partnership (CAMP) and Denso. While the Denso WRMs do not map completely into the emerging DSRC 802.11p standard, they will be the VII California standard radios through at least 2006, and will eventually be updated with compliant WRMs.

Outside the WRM and antenna, the OBE also includes other potential principal components:

- DSRC amp and antenna
    - MCX coaxial DSRC antenna connector
- Other wireless transceivers: radio card plus amp and antenna (e.g., 802.11b/g)
    - MCX coaxial 802.11b/g antenna
- GPS for positioning and UTC time synchronization
    - Including MCX coaxial GPS antenna connector
- OBE processing equipment and software
- Power
    - 110 Volt power
    - AC to DC power supply
- Connection point for ground
- Separate enclosure (potential)

The above list of components is not complete and needs further definition from car OEM stakeholders, currently DaimlerChrysler, Toyota InfoTechnology Center, BMW North America and Volkswagen/Audi.

The on-board equipment assembles information from various sensors inside the participating vehicles and communicates this data to the roadside. The data communicated is that set of information that meets the requirements of the selected use cases, as well as the needs of the participating OEMs. For the Traveler Information use case, the following information is needed:

- Vehicle ID
- Location(s)

- Heading(s)
- Time(s)
- Speed(s)

The information sent by the vehicles to the roadside unit is in the form of a message or block that contains the above data, as well as data of proprietary interest to the participating OEMs. The roadside unit sends each block of data received to a router, which transmits each block to its intended destinations, including the 511 TIC. In order to protect its proprietary interests, each participating OEM encrypts its proprietary data and provides a unique identifier such that this data goes only to it and the 511 TIC, and so that the proprietary data cannot be read at the 511 TIC. The OEMs manage data security needs for the OEM specific message sets. Security for non-OEM data will be evaluated for the testbed infrastructure and implemented accordingly.

In addition, the OBE receives travel time and incident information sent from 511 through the roadside unit and provides it to the driver through either an audio or visual display. Message set definition, including site-specific broadcast parameters, was developed during the requirements and detailed design stages of the *VII California* Program.

5.0 Roadside Component

5.1 Hardware

Part of Figure 3-1 is an architectural configuration of roadside equipment (RSE), which has been developed for use by the *VII California* Program past that milestone. At the heart of the RSE is another WRM (identical to the one in the vehicle), a port or router to landside operations (backhaul), and a specialized local safety processor with interface into the controller, e.g., Type 170 traffic signal controller.

Outside the WRM, the RSU may also include other potential principal components:

- DSRC amp and antenna
  - MCX coaxial DSRC antenna connector
- Other wireless transceivers: radio card plus amp and antenna (e.g., 802.11b/g)
  - MCX coaxial 802.11b/g antenna
- Connection to backhaul, for example, 802.11-type wireless connection, General Packet Radio Service (GPRS) modem, G3 cell modem (EV-DO, HSDPA), 802.16 (WiMAX), hardwire (DSL, T1)
- Router/hub for network access and component integration
- Separate processor and/or connection to existing controller
  - Serial connector for intersection controller or other processor, as needed
- GPS for positioning and UTC time synchronization
  - Including MCX coaxial GPS antenna connector
- Power

  - 110 Volt power
  - AC to DC power supply
- Connection point for ground
- Separate enclosure (potential): tradeoff between Type 332 cabinets or additional watertight unit

This is a joint PATH and Caltrans activity. The evolution of RSE components and configuration will be defined by PATH in conjunction with other *VII California* stakeholders. For example, with CICAS-V support, VII California will integrate a CAMP-supplied RSE in several intersections.

5.2 Functions Performed

Installation

This will be a Caltrans activity, supported by PATH. Documentation will be developed to show prototype RSU design and bill of materials, to include antennae, WAVE radios and PC/104 processors in order to replicate basic elements of the RFS prototype. At Caltrans' discretion, Caltrans and PATH will implement the first 1 – 2 RSU locations, and Caltrans will implement the remaining testbed. There will be many site-specific considerations in applying RSUs, e.g., antenna placement and optimization, varying amounts available space within cabinets. Hence, while prototyping may specify the basic configuration, the field application will require work and ingenuity from Caltrans and its partners.

Maintenance

This will be a Caltrans activity, supported by PATH for troubleshooting consultation.

Archiving

Data archiving will not be a requirement of the roadside components. All archiving will be a center-based activity.

6.0 Roadside-Center(s) Component

This component of the architecture is often referred to as the backhaul communications system. The national deployment of the backhaul communications system for VII may involve the participation of the telecommunications industry, which would provide the necessary bandwidth and technology as part of a public/private partnership arrangement. The *VII California* testbed is being designed to offer opportunities for testing of various technological and institutional arrangements.

The current *VII California* architecture enables data that has been sent by participating vehicles to the roadside units to be communicated to various destinations, including the 511 TIC and participating OEM processing centers, and enables travel time and incident data from the 511 system to be communicated to the roadside units and shared with the vehicles. The architecture also allows for remote monitoring of roadside unites from the PATH offices at the Richmond Field Station.

Currently, the *VII California* testbed relies on a leased communications system to provide for the two-way transmission of data between the centers and the roadside units. Most of the existing RSE locations use a wireless broadband technology provided by Verizon Wireless (EV-DO) for backhaul. This system provides data transfer rates up to 700 Kbps for downlinks and 150 Kbps for uplinks. There are also two RSE locations that use T1 connections for backhaul (1.4 Mbps). Finally, the *VII California* partners are exploring the use of WiMAX technology to provide backhaul at least two RSE sites.

This is an MTC-led activity. Televent Farradyne is developing the requirements for the backhaul communications for the initial *VII California* architecture, with the participation of PATH. Telvent Farradyne will continue to investigate the suitability of the existing communications system, and explore alternatives should the existing system not be suitable. Televent Farradyne is also administering the maintenance of the *VII California* network. If another communications solution is implemented, maintenance will be accounted for in the procurement.

7.0 Processing and Archiving

The availability of the vast amounts of data that VII will ultimately provide will support a wide variety of applications and will enable enhanced or new governmental and commercial services. The continuing development and testing of VII will include the development and testing of these applications. The *VII California* testbed will be available for this purpose.

The initial *VII California* architecture will include data processing and archiving capabilities. These capabilities will enable the following operations with the *VII California* probe vehicle fleet:

- Processing the location, direction, time and speed data received from the participating vehicles to calculate travel times between adjoining roadside unit locations, and other link travel times.
- Archiving all the location, direction, time and speed data received from the participating vehicles such that it can be used for evaluation and research purposes.

It is also important to note that data from the *VII California* testbed may be used by MTC's 511 system at some point in the future. Once the size of the vehicle fleet becomes large enough, the 511 system could use the processed data to enhance the travel time information it provides to the public. In addition, travel time and incident information of relevance to the locations(s) of the RSEs will be sent from the 511 system to the roadside units for transmission to the participating vehicles and drivers.

This is an MTC-led activity. The software that enables the functions defined for the initial *VII California* implementation will be developed and/or integrated by Telvent Farradyne, which will be responsible for its design, development or acquisition, testing and maintenance, and the documentation of same.

8.0 Evaluation Plan

This is an MTC-led activity, with some coordination from PATH. Additional inputs will come from *VII California* stakeholders and participants, as technical data and operational know-how will be produced from the present effort.

8.1 2005 ITS World Congress Evaluation

The initial evaluation commenced shortly after the World Congress and produced lessons learned, in essence, to build a better testbed. The evaluation included answers to:

- Did technology perform as desired? *Yes, in a demonstration-only context, without operational reliability constraints.*
- What were the limitations/constraints observed? *Limitations and constraints can be described in two dimensions, one relating very specifically to the demonstration and another related more generally to VII technology and deployment in the San Francisco Bay Area. With the former, significant demonstration-specific constraints were observed, stemming from the organization and coordination, communication, systems engineering of new installations, technologies and applications. The process of enjoining different organizations with multiple skill sets and cultures do develop hardware, firmware and software in order for the VII applications to work presented challenges at every level. These challenges were largely overcome with a successful demonstration.*

  At level of VII deployment for the San Francisco Bay Area, the jury is still out. The aforementioned limitations and constraints may not apply with a concerted effort. What was encouraging with the demonstration and a certain take-away was that multiple organizations with diverse goals were able to quickly and easily understand the significance of VII and the chosen applications to demonstrate. Less encouraging was the number of vehicles that could be marshaled for VII California, an issue that is anticipated throughout the tests that lead to decision-making, in California and elsewhere.
- Was there VII California interoperability with the privately-led World Congress Innovative Mobility Showcase? *Yes.*
- How successful was the organizational/management structure? *The informality prior to World Congress – essentially a handshake agreement between qualified parties – was maintained. A CFS was initiated after the World Congress to additionally provide VII California elements.*
- Are demonstration outcomes extensible to a larger-scale and longer-term test setting? *Yes, to the degree that additional participants were added and use cases refined; moreover, specific items of the US DOT VII POC were targeted.*

These types of questions portend technical, institutional and process improvements for the subsequent testbed and will allow *VII California* to expand in scope, participants, stakeholders, and quality based on valuable lessons learned for a "quick strike" initial deployment.

8.2 Final Evaluation

The final evaluation will include technical, impact, and institutional analysis, and, where appropriate, should include before and after analysis. The full evaluation of the use cases could include agency and industry partner interviews regarding institutional and technical issues, surveys, observational analysis, interviews, and focus groups. The methodology to evaluate each use case will depend on the specific attributes of the technology and the persons exposed to the technology. For all use cases, technical, impact, and institutional variables will be assessed as appropriate.

Technical: The technical evaluation should focus on the hardware and software operation of the demonstration. Did the technology perform as expected/desired? Consideration should be given to: identification of key stakeholder partners; eliciting from the partners a meaningful set of goals and objectives for the project and their relative priorities; identifying and obtaining insight and consensus regarding which measures will indicate the degree to which project success has been achieved; and communicating changes in goals, objectives, and measures as the project progresses.

Impact: Impacts on VMT, safety, mobility, mode choice, transportation system efficiency, productivity of transportation providers, air quality, energy efficiency, etc. may be examined, as appropriate. Performance measures and corresponding metrics would be identified for study. Measures could include: reduction in the overall rate of crashes; reduction in delay; improvement in customer satisfaction; increases in freeway and arterial throughput or effective capacity; decrease in emissions levels; decrease in energy consumption; and cost savings. The level of detail and the opportunity to complete before and after analysis will be determined to a large extent by the size and duration of each use case. If the demonstration size is too small it may not be possible to study some of the broader societal impacts.

Institutional: Researchers would document lessons learned regarding institutional (State and Federal) challenges (what worked and what didn't) and make recommendations for improvements (both institutional and procedural). This evaluation would also include a broader assessment of lessons learned regarding the public-public and public-private relationships for VII deployment.

Broadly these three evaluation components (technical, impact, and institutional) should culminate in policy recommendations for the direction of further VII California deployments, and relationships among agencies and between agency and industry, including institutional challenges, recommended solutions, and next steps.