

# *VII California* **Concept of Operations**

A Collaboration of Metropolitan Transportation Commission  
(MTC), Caltrans, DaimlerChrysler and Volkswagen/Audi

University of California Partners for Advanced Transit and Highways (Caltrans) and  
Parsons-Brinkerhoff Farradyne (MTC), Contractors

July 21, 2005

## 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 first version 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, DaimlerChrysler and Volkswagen/Audi activity. Multiple collaborating partners are further sought as co-developers and, ultimately, “owners.” In the current work, California PATH will be working with Caltrans on the infrastructure (roadside unit) implementation and vehicle-infrastructure messaging and communication of the VII data, whereas PB Farradyne will be working with MTC on backhaul communications and collection, processing and archiving of data at the center.

### 1.0 Goals<sup>1</sup>

As documented in the *VII California White Paper* and *VII California Program Plan Outline*, the overall goals of the *VII California* program are to:

- Better manage the safety and productivity of the surface transportation system;
- Benefit from the synergy of public sector, auto industry, and other private sector innovations; and
- Build upon California’s already considerable existing infrastructure investments.

While these goals are appropriate for the overall VII California Program, the VII California Working Group has established more tangible, near-term goals for the VII testbed. These include:

---

<sup>1</sup> Obtained from pp. 6 – 8 of *VII California Development and Deployment* program plan.

- Provide a testbed to understand the technical feasibility and institutional value of VII;
- Inform future decisions for the National VII Program;
- 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 through 2007 over which time both the overarching goals and the testbed goals will be realized. The VII California Working Group plans to develop the testbed in three phases: Initial Development, 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.

Task	Task Name	Start	Finish	2004		2005				2006				2007			
				Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 0	Project Management	July '04	Dec '07														
<b>Phase 1 Initial Development</b>																	
Task 1.1	Develop High-Level VIIC Master Plan	July '04	Dec '04														
Task 1.2	Produce VIIC Vision	July '04	Dec '04														
Task 1.3	Develop VIIC Concept of Operations	Mar '05	May '05														
Task 1.4	Derive VIIC Requirements	Apr '05	Jun '06														
<b>Phase 2 WC Demonstration</b>																	
Task 2.1	Conduct WC Detailed Design	Apr '05	Jun '06														
Task 2.1.1	Vehicle-RSU Design	Apr '05	Jun '06														
Task 2.1.2	RSU-Center Design	Apr '05	Jun '06														
Task 2.2	Develop and Install WC Elements	May '05	Sep '05														
Task 2.2.1	Develop and Install Vehicle-RSU Apps	May '05	Sep '05														
Task 2.2.2	Develop and Install RSU-Center Apps	Jul '05	Sep '05														
Task 2.3	Test Individual WC Use Cases	Sep '05	Oct '05														
Task 2.4	Conduct WC Demonstration	Nov '05	Nov '05														
Task 2.5	Evaluate WC Demonstration	Mar '05	Mar '06														
<b>Phase 3 VII Proof of Concept</b>																	
Task 3.1	Conduct Detailed Design	Jun '06	Sep '06														
Task 3.2	Develop and Install Elements	Sep '06	Mar '07														
Task 3.3	Conduct Component Testing	Apr '07	May '07														
Task 3.4	Conduct System Testing	May '07	Jun '07														
Task 3.5	Evaluate Proof of Concept	Jul '07	Dec '07														
Task 3.6	Operate and Maintain VII Test Bed	Jul '07	?														

**Figure 1-1. VII California is designed to provide California with a VII demonstration for the 2005 ITS World Congress and then a VII test bed for use in a Proof of Concept. It sets the stage for potential VII deployment.**

To support the VII California Program goals, the first milestone for *VII California* will be to provide up to 40 roadside units (RSU) 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 objectives of this first substantial *VII California* activity 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.

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

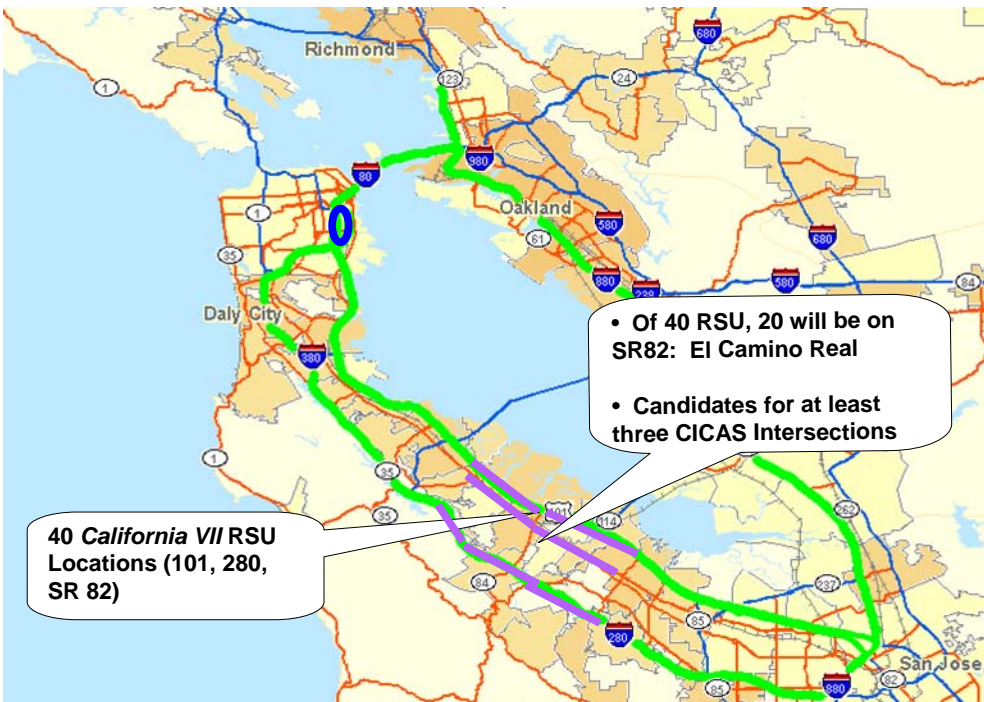


Figure 1-2. Potential RSU Cabinet Locations

## 2.0 Use Cases<sup>2</sup>

The first step in developing the Concept of Operations will be to determine appropriate use cases for both the longer-term testbed and, of more immediate consequence, for the World Congress milestone.

Longer-term use cases will be drawn from those briefly described below:

1. **Vehicles as Traffic Probes** – The vehicles shall send raw location, time, speed and direction information to roadside units (RSU) which will pass the raw data along to a central processing center where it will be used to create timely and accurate real-time traveler information. The central processing center would be the 511/TravInfo™ system. The traveler information shall be disseminated to the Caltrans District 4 TMC and to the public via the 511/TravInfo™ system.
2. **Intelligent On-Ramp Metering** – This application involves using wireless-equipped vehicles to measure real-time traffic density on the highway so that on-ramp signal phasing can be dynamically adjusted to maximize mainline traffic flow.
3. **Vehicle Probes Provide Weather Data** – The vehicles provide location and direction information, along with the status of on-board sensors (temperature, precipitation, sun, level, traction control, etc.) and the status of on-board devices (headlights, wipers, heater, air conditioner, etc.) to the central processing center so it can determine the real-time weather conditions on the roadway.
4. **Travel Time Data to Vehicles** – The central processing center sends accurate and up-to-date link travel times to the RSU and then the vehicle for use in real-time dynamic routing. The travel times will be generated by the 511/TravInfo™ system.
5. **Incident Information to Vehicles** - The central processing center transmits real-time incident information to the RSU and then the vehicle, which can be programmed to present this information to the driver in accordance with installed equipment and selected options. The incident information will originate from the 511/TravInfo™ system.
6. **In-Vehicle Signage** – In-vehicle signing refers to the display (and annunciation, where necessary) of available roadside sign information inside the vehicle. This information would be transmitted via RSUs. The information can describe features about the local area such as speed limits or services that are provided in the near vicinity.
7. **Work Zone Safety Warning** - Work zone safety warning refers to the detection of a vehicle in an active work zone area and the indication of a warning to its driver. RSUs would broadcast the warning data to vehicles as they approach a work zone or construction zone.
8. **Intersection Collision Warning** – This is the application of safety critical messaging between vehicles and roadside equipment for cooperative intersection safety, focused on signal violation and left-turn crashes. Such an application would likely require low latency communications concepts such as the 5.9 GHz-dedicated short-range

---

<sup>2</sup> Obtained from pp. 6 – 8 of VII California Development and Deployment program plan.

communications (DSRC). This potential use case differs from the others because the implementation envisioned under VII California may be prototypical.

9. **Curve Overspeed Warning** – Another application of low latency safety critical messaging would be curve overspeed warning, wherein road curvature (and potentially, road surface condition) would be broadcast to vehicles, and vehicles would combine this information with their dynamic state to provide in-vehicle warning and, as desired, correction. An extension would be that vehicles that issue curve overspeed alerts would transmit such information to the roadside, enacting a general warning to unequipped vehicles.

It is possible that some of the use cases above may be combined into a single application, e.g., in-vehicle signage may also include work zone warnings or incident information. Moreover, the above list may be refined as more input is received from car manufacturer stakeholders.

Through VII California Working Group meetings, six use cases have been selected for the VII deployment aimed at the World Congress milestone. The six demonstrated use cases are a subset of the above, namely:

1. **Vehicles as Traffic Probes** – Data from vehicles is sent to the central processing center and used to calculate travel times along specified links, routes or paths.
2. **Travel Time Data to Vehicles** – The central processing center sends accurate and up-to-date link travel times to the RSU and then the vehicle for use in real-time dynamic routing. The travel times will be generated by the 511/TravInfo™ system.
3. **Incident Information to Vehicles** - The central processing center transmits real-time incident information to the RSU and then the vehicle, which can be programmed to present this information to the driver in accordance with installed equipment and selected options. The incident information will originate from the 511/TravInfo™ system.
4. **Intersection Collision Warning** – The local signal controller transmits signal timing (phase condition) information to the RSU and then the vehicle.
5. **In-Vehicle Signage** – Integration of roadside signage information into in-vehicle navigation system, e.g., speed limit, next exit information. Lays migration path to work zone warning.
6. **OEM Specific Application** – Encrypted message set specific to Original Equipment Manufacturer (OEM) requirements, passed between vehicle, RSU and OEM center.

Comment [bm1]: Shouldn't we specify the format that this data will be sent (i.e. text versus wave files)?

Comment [bm2]: Same comment as above.

### 3.0 Architecture

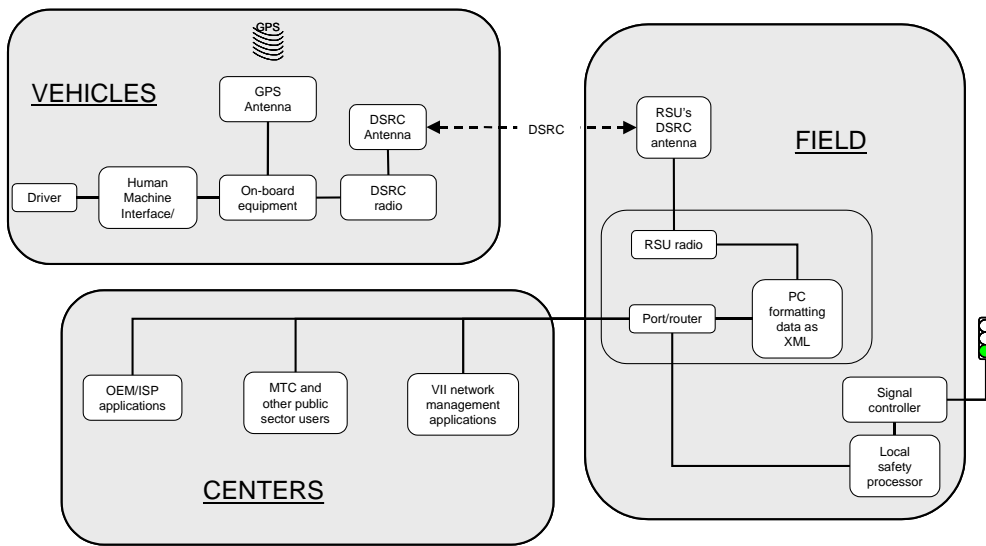
The VII California architecture will be a framework that depicts how information needed to enable a variety of use cases will flow between vehicles and TMCs, vehicle OEMs and other commercial locations, and how that information will be processed, stored and used for operational and evaluation purposes 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 1.0 of this national VII architecture was published in April, 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.

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 will be implemented for the 2005 World Congress. For expediency, a number of elements or features of Version 1.0 of the national VII architecture will not be included in the initial architecture.

### WC Demo VII Architecture – Physical Entities



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

As described more fully below, the initial VII California architecture will enable the communication of data from equipment located on-board participating vehicles to roadside units deployed at selected locations. From there, the data will be communicated to several locations, including the 511/TravInfo<sup>®</sup> Travel Information Center, and to OEM

processing centers, through a router and the appropriate addressing schemes. Data from the 511/TravInfo<sup>®</sup> TIC and the OEM locations will also be communicated back to the roadside units, through them to the participating vehicle on-board equipment, and then 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 will be done through an onboard global positioning system (GPS) unit, which will include 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 (WASS) or use of High Accuracy Nationwide 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 WRM’s developed by the Collision Avoidance Metrics Partnership (CAMP) and Denso. While the Denso WRM do not map completely into the emerging DSRC 802.11p standard, they will be the VII California standard radios through at least the World Congress demonstration.

Outside the WRM and antenna, the OBE will 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
- 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 and Volkswagen/Audi.

The on-board equipment will assemble information from various sensors inside the participating vehicles and communicate this information to the roadside. The information that will be communicated will be that set of information that meets the requirements of the selected World Congress use cases, as well as the needs of the participating OEMs. For the Vehicles as Probes use case, the following information will be needed:

- Vehicle ID
- Location(s)
- Heading(s)
- Time(s)
- Speed(s)

The information sent by the vehicles to the roadside unit will be in the form of a message or block that will contain the above data, as well as data of proprietary interest to the participating OEMs. The roadside unit will send each block of data received to a router which will transmit each block to its intended destinations, including the 511/TravInfo<sup>®</sup> TIC. In order to protect its proprietary interests, each participating OEM will encrypt its proprietary data and provide a unique identifier such that this data goes only to it and the 511/TravInfo<sup>®</sup> TIC, and so that the proprietary data cannot be read at the 511/TravInfo<sup>®</sup> TIC. For the World Congress demo, OEMs will manage data security needs for the OEM specific message sets. Security for non-OEM data will not be implemented but will be evaluated for the subsequent testbed infrastructure and implemented accordingly.

Comment [bm3]: Did the OEMs agree to this? Is this ID in our message set?

In addition, the OBE will receive travel time and incident information sent from 511/TravInfo<sup>™</sup> through the roadside unit and provide it to the driver through either an audio or visual display. Message set definition including site specific broadcast parameters will be developed during the requirements and detailed design stages of the California VII program.

## 5.0 Roadside Component

### 5.1 Hardware

Part of Figure 3-1 is an architectural configuration of roadside equipment (RSE), which will be developed prior to the World Congress but are intended for use for VII California past that milestone. At the heart of the RSE are again WRM, a port or router to landside operations and a specialized local safety processor with interface into the controller, e.g., Type 170 traffic signal controller.

Comment [bm4]: Is this part of the RSE or separate?

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 (e.g., 802.11-type wireless connection, (General Packet Radio Service or GPRS modem, hardwire)
- 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 above list of components is not yet complete; therefore, RSU components and configuration will be defined by PATH in conjunction with other VII California stakeholders.

## **5.2 Functions Performed**

### *Development and Prototyping*

This is a joint PATH and Caltrans activity, with significant stakeholder input. PATH will acquire and install a Type 332A cabinet and associated hardware at the University of California Richmond Field Station (RFS) “intelligent intersection” facility. The 332A cabinet is commonly found at Caltrans intersections and roadsides and will serve as a prototype unit. From this unit, stakeholders will have access to nominal RSU to develop their interfaces.

Specific prototype development directions will include:

- a. Design of autonomous processors for each RSU to allow minimal existing infrastructure modification. This will necessitate a robust computational platform, most likely a PC/104.
- b. Design of DSRC antenna and WRM integrated as transceiver subsystem for optimal performance and installation ease, connected by ethernet to processor. Prior antenna design has not been optimized for RSU.
- c. 802.11b/g amplifier and antenna coupled to the processor, in anticipation of a collateral requirement that will require provision of WiFi functionality for some VII services.
- d. GPRS serial port modem connection to processor for backhaul connection, for data as well as RSU maintenance purposes.

- e. Disk storage, with requirement heavily dependent on use case development.
- f. Embedded operating system for real-time communication response and small software footprint. While at this (ConOps) stage, design options are open; because VII involves safety-critical applications, we will likely eschew the use of MS Windows, opting for a reliable, robust RTOS.

### 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 our prototyping may specify the basic configuration, the field application will require work and ingenuity from our Caltrans 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 will be designed to offer opportunities for testing of various technological and institutional arrangements.

The initial VII California architecture deployed for the World Congress will enable data that has been sent by participating vehicles to the roadside units to be communicated to various destinations, including the 511/TravInfo<sup>®</sup> TIC and participating OEM processing centers, and enable travel time and incident data from the 511/TravInfo<sup>®</sup> system to be communicated to the roadside units. Because relatively few vehicles will be participating, and for expediency reasons, an existing GPRS communications system will likely be the primary medium to be used to provide for the two-way transmission of data among the 511/TravInfo<sup>®</sup> TIC, OEMs and the roadside units. Demonstration of a high bandwidth solution at a select RSU site will be investigated for the World Congress. Remote monitoring (center-based) of roadside units and the supporting network will not be an element of the World Congress demo but will be included in the subsequent testbed infrastructure.

This is an MTC-led activity. The requirements for the backhaul communications for the initial *VII California* architecture to be implemented for the World Congress will be developed by PB Farradyne with the participation of PATH. PB Farradyne will investigate the suitability of the existing GPRS communications system, and explore alternatives should the existing GPRS system not be suitable. PB Farradyne will make the necessary arrangements to ensure that the selected communications system is available in sufficient time prior to the World Congress for testing activities. The maintenance of the GPRS network will be administered by PB Farradyne. 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 make available will support a wide variety of applications that will enable enhanced or new governmental or 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. For the World Congress demo, data archiving will be implemented for only data directed to the 511/TravInfo<sup>®</sup> system

The 511/TravInfo<sup>®</sup> system will also be leveraged into the *VII California* probe vehicles; travel time and incident information of relevance to the locations(s) of the RSUs from the 511/TravInfo<sup>®</sup> system will be sent 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 World Congress *VII California* implementation will be developed and/or integrated by PB Farradyne, which will be responsible for their 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 the PATH, as PATH is the Caltrans-sponsored evaluator of the World Congress Innovative Corridors Initiative.

**Comment [bm5]:** For the bullets below, we should distinguish between the travel times generated by 511 and the travel times that will be calculated from the probe vehicles. These will not be the same thing. Note that we will not use any of the travel times from probes in our live 511 system. We will only be evaluating them.

Additional inputs will come from VII California stakeholders and participants, as technical data and operational know-how will be produced from the present effort.

The evaluation will be conducted in two steps: an initial evaluation after the World Congress, and a final evaluation at the conclusion of the VII California testbed development in 2007.

**Comment [bm6]:** We need to expand here on what we will be evaluating (e.g. how well the architecture performs, usefulness of the data, etc.). Refer to the write up in the SOW to add more detail to this section.

### **8.1 Initial Evaluation**

The initial evaluation will commence shortly after the World Congress and is intended to produce lessons learned, in essence, to build a better test bed. In many respects, it will come at an ideal time – after the first, quick iteration where initial installation and operation are key but before the second, more studied iteration where long-range objectives take over. The focus will be on what is learned and some of the important questions asked in the evaluation will include:

- Did technology perform as desired?
- What were the limitations/constraints observed?
- Was there VII California interoperability with the privately-led World Congress Innovative Mobility Showcase?
- How successful was the organizational/management structure?
- Are demonstration outcomes extensible to a larger-scale and longer-term test setting?

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.