FUNCTIONAL REQUIREMENTS

SAN MATEO COUNTY SMART CORRIDORS PROGRAM

FOR

SMCTA / CALTRANS / C/CAG

Prepared by:

URS

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VERSION: #12000.007

FUNCTIONAL REQUIREMENTS

1.0 Introduction and Background

1.1 Introduction and Background

The City/County Association of Governments of San Mateo County (C/CAG) and the San Mateo County Transportation Authority (SMCTA) in conjunction with the California Department of Transportation (Caltrans) has initiated an effort to address the operation of the freeway and arterial roadway network in San Mateo County. The San Mateo County Smart Corridor Program is intended to benefit a variety of users including commuters, local traffic, commercial vehicle and transit operators.

The mitigation of the impacts of non-recurring traffic congestion on local streets within San Mateo County during major freeway incidents on US-101 was identified as a high-priority project in the Smart Corridor Program. A Project Report (PR) was written that proposes the deployment of integrated Intelligent Transportation System (ITS) elements to provide local agencies and Caltrans the tools to manage this congestion. The project includes the installation of the following ITS elements:

- Trailblazer signs to direct traffic;
- Fixed or pan-tilt-zoom closed-circuit television cameras at intersections and midblock locations to monitor traffic congestion and end-of-queue location;
- Communications to provide interconnect between local agency traffic signals on local streets and State operated traffic signals on State routes;
- Upgraded traffic signal controllers and/or cabinets and signal operation software systems;
- Arterial changeable message signs to inform motorists of traffic conditions;
- Center-to-center communications between the proposed San Mateo County Hub (SMCHub) and the Caltrans District 4 Transportation Management Center (D4TMC) (note where TMC is used in a general manner in this document, it refers to the SMCHub, the D4TMC and local TMCs);
- Vehicle detector stations (non-intrusive or intrusive technology) on non-freeway state routes (El Camino Real) and local streets at mid-block locations.

Many of these same elements can also be used to manage traffic along the corridor during recurrent congestion. In addition to the ITS elements noted above, the following ITS elements were identified for possible deployment on future projects:

- Transit priority service at intersections;
- Emergency vehicle preemption at intersections;
- Highway Advisory Radio (HAR) transmitters and signs;
- Advance warning signs at Caltrain at-grade crossings;
- Changeable message signs for arterial travel times.

A Concept of Operations (ConOps) was prepared in October 2008 and updated in September 2009, with input from local agencies and Caltrans, and direction from the Federal Highway Administration (FHWA). This is an initial step in the Systems Engineering process defined by the FHWA. This document identifies the stakeholders, their roles and responsibilities, their coordination with each other, and how the system will be developed.

1.2 Relevant Documents

Relevant documents include:

- FHWA/Caltrans Systems Engineering Guidebook for ITS, version 2.0, January 2007
- Final Draft ITS Infrastructure Improvement Plan, San Mateo County Alternative Route Plan, January 2008
- Draft Project Report in San Mateo County on US-101 and SR-82 from I-380 to the Santa Clara County Line 04-SM-101-PM 0.00/20.72, 04-SM-82-PM 0.00/18.96, San Mateo County Smart Corridors, EA 4A9200, 04-SM, October 2008
- Project Study Report to Request Programming in the STIP for Phase 1of the San Mateo County Smart Corridors, March 2008
- San Mateo County Smart Corridors Projects Traffic Light Synchronization Program Funding Application March 2008
- San Mateo County Arterial Route for Traffic Incident Guide, February 2009
- San Mateo County Smart Corridors Program Concept of Operations, September 2009
- System Engineering Management Plan, San Mateo County Smart Corridors Program, version 10000.004, September 2009

Definitions and acronyms in this document are defined in the System Engineering Management Plan noted above.

2.0 Scope of Project

The goals of the project identified in the Concept of Operations have been modified as shown in **Table 1**.

Table 1 – Project Goals

Goal Area	Smart Corridors Program Goals
Traffic Incident Management	• Proactively manage traffic already diverted from the freeway to minimize impacts on local arterials, and return regional traffic back to the freeway as soon as possible by: o Actively managing traffic signal operations on selected routes to maximize traffic flow around a major incident and minimize delays caused by diverted freeway traffic. o Improving collection of current travel condition information along local arterials on the alternate routes. (Future) o Providing accurate and timely route guidance information about the corridors to agency transportation managers. (Future) o Minimizing the intrusion of freeway traffic on local streets due to major freeway incidents.

Interagency Coordination	• Provide the capability for shared control and operation of the Smart Corridors components by the agencies. • Improve sharing of resources between agencies for more unified transportation management operations across jurisdictions • Improve communications between the agencies during major freeway incidents
Traffic Operations and Management	• Improve traffic flow within the corridor during normal operation • Share traffic information between the agencies to improve coordination and management of traffic during normal operations

3.0 Purpose of Document

3.1 Document Purpose:

3.1.1 Identify the functional requirements of the ITS subsystems and system comprising the San Mateo Smart Corridors Program

3.1.2 Describe case studies of how the system will look like from the public's view, the D4TMC operator's view and the local Agency view when a major incident occurs on US-101

3.1.3 Identify the methods of verifying the functional requirements

3.1.4 Trace the functional requirements from the ConOps

4.0 Operational Scenarios Under Incident Conditions

4.1 Incidents

4.1.1 Incidents will occur on a regular basis on US-101. They cannot be predicted but the likelihood of their occurring in a given time period at a given location can be postulated.

4.1.2 The steps involved in the life of an incident are as follows:

- Incident detection through detection algorithms, motorist calls, or notification from public safety officials, etc.
- Incident verification through CCTV, or onsite confirmation
- Incident response -- this will include notification of the needed personnel and mobilization of equipment
- Incident management and clearance -- involves the management of an incident while it is in progress with the aim of clearing the incident. The San Mateo Smart Corridors Program will be most effective during this step.
- Incident closure -- this occurs when response teams are no longer needed onsite. Note that the impact of incidents on traffic congestion can continue to occur for hours afterward.

4.1.3. Scenarios

4.1.3.1 The following figures illustrate how the proposed system is expected to function from three perspectives:

- From the view of a D4TMC operator (Figure 1)
- From the view of the driver's perspective (Figure 2)
- From the view of a local TMC/SMCHub operator (Figure 3)

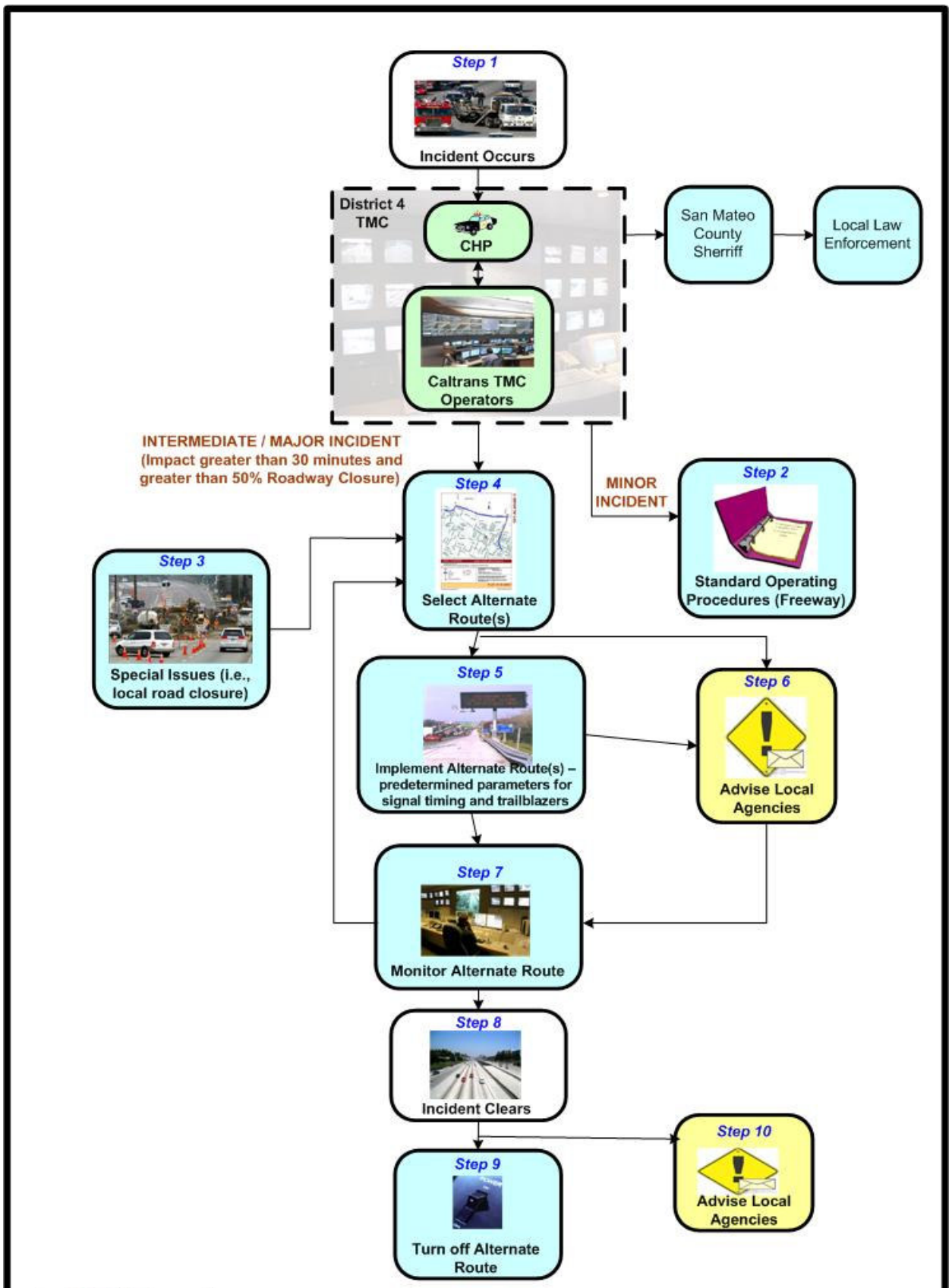
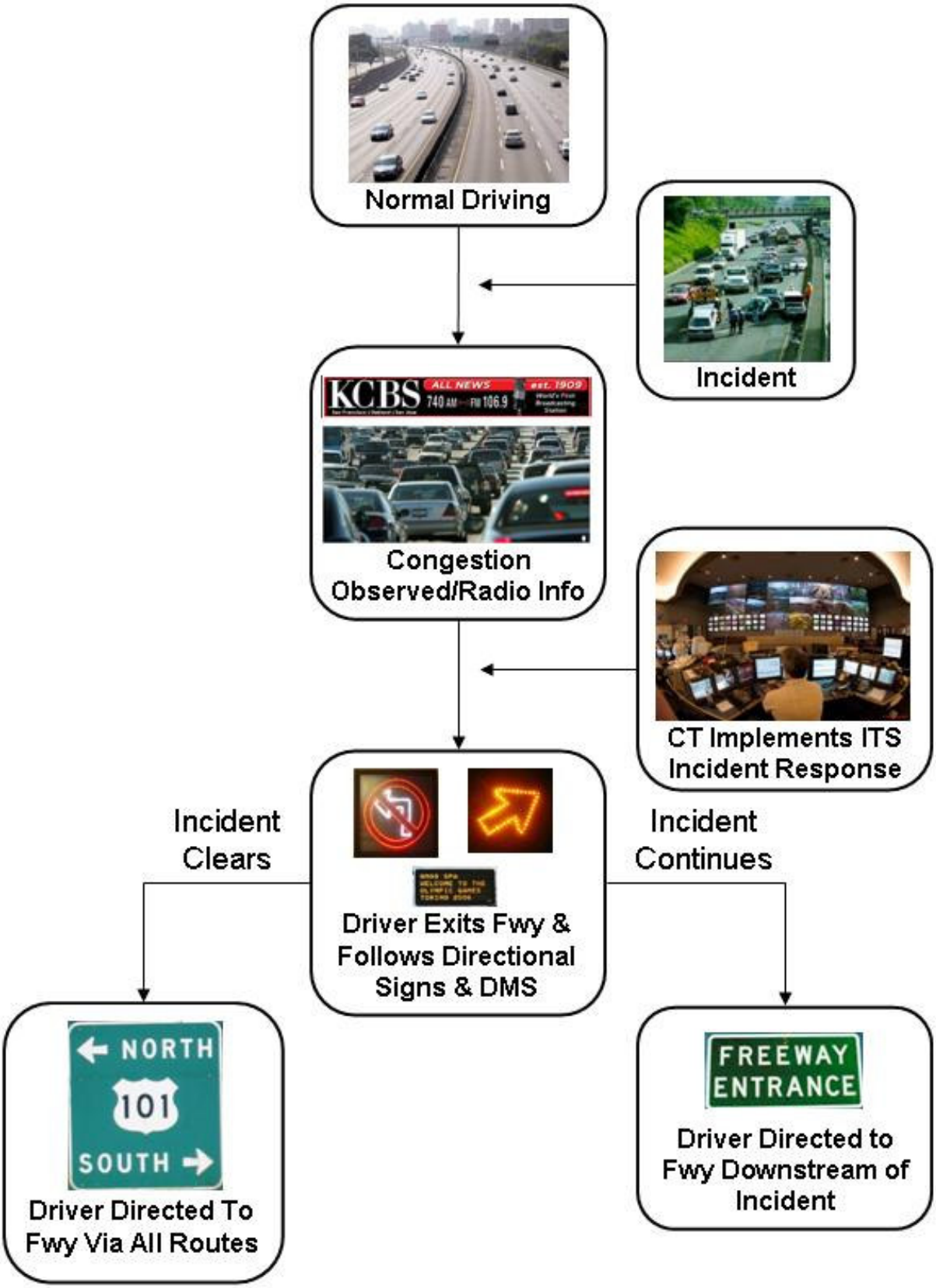
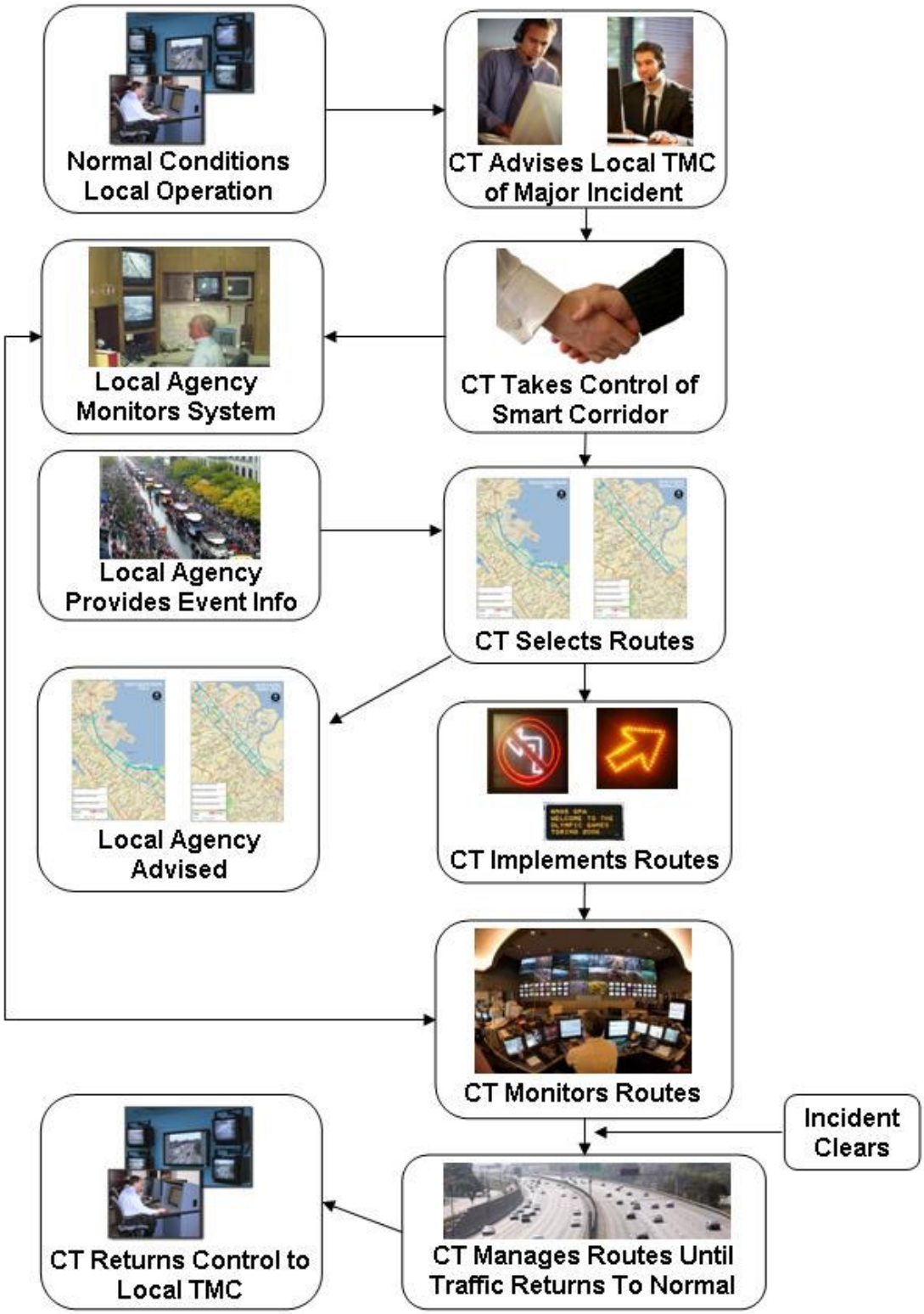


Figure 1-San Mateo County Smart Corridors Incident Flow Diagram

Driver's Perspective (Managed Route)
Figure 2



Local TMC/SMCHub Perspective
Figure 3



5.0 Functional Requirements

5.1 Overall System Requirements

5.1.1 The System shall be able to collect and display data to support traffic management.

5.1.2 The System shall deploy ITS field elements to support the following functions:

- Traffic control
- Motorist information
- Traffic monitoring

5.1.3 The System shall be capable of interfacing with existing and planned ITS elements at all TMC levels.

5.1.4 The System shall support operation by multiple concurrent users/operators.

5.1.5 The System shall support non-incident operation by multiple jurisdictions.

5.1.6 The System shall allow a hierarchy of users.

5.1.7 The System shall be capable of collecting, displaying and sharing information.

5.1.8 The System shall be able to be expanded.

5.1.9 The System shall be secure.

5.1.10 All field and TMC equipment shall be readily accessible in a safe manner for maintenance.

5.1.11 The System as a whole and each Subsystem shall maximize use of commercial-off-the-shelf (COTS) software and hardware products and applications.

5.1.12 The System as a whole and each Subsystem should support industry standards to allow multiple types of field equipment from multiple manufacturers to operate as an integrated system.

5.1.13 The System, each Subsystem and the associated field equipment shall have a fail safe mode.

5.1.14 The System and each Subsystem shall have high availability.

5.1.15 Control during incidents shall be from the D4TMC.

5.1.16 The System shall be designed to delineate maintenance responsibility.

5.1.17 The System shall be able to collect data that can be used to determine conformance with performance measures.

5.2 Traffic Control

5.2.1 The Subsystem shall collect and maintain all data required for monitoring and displaying traffic information from selected intersections.

5.2.2 The Subsystem shall be capable of controlling and monitoring the operation of traffic signal equipment at selected intersections.

5.3 Motorist Information

5.3.1 Direction information on alternate routes shall be provided to motorists.

5.3.2 Signs shall be clearly distinguishable from other signage.

5.3.3 Signage shall be used to help manage the surface transportation system.

5.3.4 Enroute traveler information shall be provided to the motorist.

5.4 Traffic Monitoring

5.4.1 Surveillance shall be used to view the surface transportation system.

5.4.2 The Subsystem shall support the monitoring of traffic at selected locations.

5.4.3 Data from the monitoring system shall be transmitted to the TMC for analysis within the traffic control system.

5.5 Communications Network

5.5.1 Provide capability for center-to-field (C2F) communications.

5.5.2 Provide capability for center to center (C2C) communications.

6.0 Verification Methods

6.1 Testing Steps

6.1.1 Unit testing -- This testing is done to ensure that each component (hardware and software) meets its respective requirements.

6.1.2 Subsystem integration and verification -- Verification ensures that what was built matches the requirements. This is performed at various levels of the subsystem starting with lowest level and integrating other levels upon successful completion of the testing of the previous level.

6.1.3 System verification -- This is done in two stages. The first stage is the integration of one unit of each subsystem into a system in bench test. The second stage is the testing of this integrated system either onsite or in the field. This is frequently the last time many requirements will be verified and, as a result, this step is the most formal, reviewed, and witnessed. While it may not be as exhaustive as subsystem verification, it needs to be extensive enough to convince stakeholders the system does what it is supposed to do.

6.1.4 System deployment -- This testing is performed by installing all field and central components and testing the system as a whole to ensure operability. A system acceptance test to verify that the system meets all of its requirements will be performed at this time. Prior to deployment, an operational review is held to ensure that all training and support for the system is in place and that the operations and maintenance personnel are designated.

6.1.5 System validation -- Validation confirms that the system meets the intended needs of the owner and the stakeholders. Validation begins early in the design process to ensure that the requirements developed meet the stakeholder needs, goals and objectives. A formal validation test will be performed after system acceptance. This test assesses the system's performance against the project needs, goals and expectations.

6.2 Testing Alternatives

6.2.1 Inspection -- this is the visual verification of requirements such as color, size, intactness or model number. This will include comparing the documents provided to the requirements noted in the project design documents. Additionally, documentation provided will be compared to the component to which it relates.

6.2.2 Analysis -- this is the mathematical analysis of collected data to verify a requirement.

6.2.3 Demonstration -- this is the use of the system itself to verify the expected output such as a response to an operator input. This is the most commonly used verification technique. A component or subsystem will be used to demonstrate a functional documented in the project design documents. This may be done by providing real time inputs, simulated inputs and/or archival inputs to determine if the output provided meets the project requirements. A burn-in is a special type of demonstration to identify and resolve random or latent defects (thermal, memory leaks, non continuous operation, etc.).

6.2.4 Test -- this is similar to demonstration except external test equipment is used.

7.0 Traceability Matrix

7.1 Traceability

7.1.1 Traceability follows the life of a requirement throughout the life of the system. It is the key cross-cutting process that supports verification and validation requirements by ensuring that

all needs are traced to requirements and the detailed design. Traceability also verifies all requirements are implemented, verified and validated. Traceability supports impact analysis and configuration management for long term maintenance, changes, upgrades and replacements.

7.1.2 Traceability is typically done by mapping requirements in the ConOps to the functional requirements and the high level requirements. They are then mapped to the verification/test plans/procedures.

The Traceability Matrix is shown in the Appendix and will be updated as the project proceeds.

Appendix 1
Traceability Matrix

TRACEABILITY MATRIX-SAN MATEO SMART CORRIDORS PROGRAM-SYSTEM ENGINEERING

Concept of Operations Sept 2009 Reference Section	ConOps Description	Functional Requirements #12000.007 Reference Section	Functional Requirements Description	High Level Requirements Reference	High Level Requirements Description	Tested By /Date	Accepted/Rejected (A/R)	A/R Date	Comments
3.1	**Incident Management**								
3.1.1	Install trailblazers on designated routes to guide traffic	5.3.1	Direction information on alternate routes shall be provided to motorists.						
		5.3.3	Signage shall be used to help manage the surface transportation system						
		5.3.4	Enroute traveler information shall be provided to the motorist						
3.1.2	Integrate traffic incident management strategies across multiple local agencies and Caltrans	5.1.4	The System shall support operation by multiple concurrent users/operators						
		5.2.2	The Subsystem shall be capable of controlling and monitoring the operation of traffic signal equipment at selected intersections.						
		5.1.15	Control during incidents shall be from the D4TMC						
3.1.3	Implement devices to manage freeway traffic that diverts around major incidents	5.3.1	Direction information on alternate routes shall be provided to motorists.						
		5.3.2	Signs shall be clearly distinguishable from other signage.						
3.1.4	Proactively manage diverted traffic to minimize local congestion	5.1.2	The System shall deploy ITS field elements to support the following functions: Traffic control Motorist information Traffic monitoring						
		5.2.2	The Subsystem shall be capable of controlling and monitoring the operation of traffic signal equipment at selected intersections.						
		5.3.3	Signage shall be used to help manage the surface transportation system						
		5.3.4	Enroute traveler information shall be provided to the motorist.						
		5.4.3	Data from the monitoring system shall be transmitted to the TMC for analysis within the traffic control system.						
3.1.5	Integrate SM Smart Corridors via the Bay Area Center-to-Center Network	5.5.2	Provide capability for center to center (C2C) communications.						
3.1.6	Provide for remote monitoring of local street traffic flow through the use of video cameras	5.4.1	Surveillance shall be used to view the surface transportation system.						
		5.4.2	The Subsystem shall support the monitoring of traffic at selected locations.						
3.1.7	Maximize green phasing along alternate routes	5.2.2	The Subsystem shall be capable of controlling and monitoring the operation of traffic signal equipment at selected intersections.						

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3.1.8	Provide local site for monitoring and operations	5.1.4	The System shall support operation by multiple concurrent users/operators						
		5.1.5	The System shall support non-incident operation by multiple jurisdictions						
3.1.9	Provide a Hub in San Mateo County for central monitoring and management of traffic on local streets and as a backup to the D4TMC	5.1.4	The System shall support operation by multiple concurrent users/operators						
		5.1.5	The System shall support non-incident operation by multiple jurisdictions						
3.2	**Arterial Management**								
3.2.1	Implement traffic responsive and time of day signal timing from a remote location	5.2.2	The Subsystem shall be capable of controlling and monitoring the operation of traffic signal equipment at selected intersections.						
3.2.2	Maximize green phasing along major corridors	5.2.2	The Subsystem shall be capable of controlling and monitoring the operation of traffic signal equipment at selected intersections.						
3.2.3	Upgrade controllers and communications infrastructure	5.1.3	The System shall be capable of interfacing with existing and planned ITS elements at all TMC levels.						
		5.5.1	Provide capability for center-to-field (C2F) communications.						
3.2.4	Improve data collection of real-time travel conditions through system detection. Dissemination of real-time travel conditions is a possible future enhancement.	5.4.2	The Subsystem shall support the monitoring of traffic at selected locations.						
3.2.5	Enable remote monitoring of real-time travel conditions	5.2.1	The Subsystem shall collect and maintain all data required for monitoring and displaying traffic information from selected intersections.						
		5.1.7	The System shall be capable of collecting, displaying and sharing information.						
		5.1.9	The System shall be secure.						
3.2.6	Integrate traffic signals across jurisdictions	5.2.2	The Subsystem shall be capable of controlling and monitoring the operation of traffic signal equipment at selected intersections.						
3.2.7	Improve traffic management for normal traffic operations	5.1.5	The System shall support non-incident operation by multiple jurisdictions.						
		5.1.1	The System shall be able to collect and display data to support traffic management.						
3.2.8	Maintain functionality of existing legacy systems	5.1.3	The System shall be capable of interfacing with existing and planned ITS elements at all TMC levels.						
3.3	**Traveler Information**								

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3.3.1	Provide travel times on local streets by using system detection or other technology	Future							
3.3.2	Use C2C between SM Smart Corridors and Caltrans	5.5.2	Provide capability for center to center (C2C) communications.						
		5.1.12	The System as a whole and each Subsystem should support industry standards to allow multiple types of field equipment from multiple manufacturers to operate as an integrated system.						
3.3.3	Integrate with Bay Area 511 (future)	Through Caltrans							
3.4	**Transit Management**								
3.4.1	Implement transit signal priority	Future							
3.4.2	Disseminate transit travel times	Future							
3.4.3	Provide advance warning and clearance of at-grade crossings.	Future							
3.4.4	Utilize transit GPS to acquire travel time information	Future							
3.5	**System Operations and Maintenance**								
3.5.1	Clear notation of which agency owns and operates each element	5.1.10	All field and TMC equipment shall be readily accessible in a safe manner for maintenance.						
		5.1.16	The System shall be designed to delineate maintenance responsibility.						
3.5.2	Utilize technology that will not require substantial software development. Provide device status and failure notification	5.1.11	The System as a whole and each Subsystem shall maximize use of commercial off the shelf (COTS) software and hardware products and applications.						
3.5.3	Not dependent on other systems for operability	5.1.14	The System and each Subsystem shall have high availability.						
3.5.4	All Caltrans elements operate during power outages using back-up power sources	5.1.13	The System each Subsystem and the associated field equipment shall have a fail safe mode.						
5.2	**Operational Strategies**								
5.2.1	Under normal operations, each agency will be responsible for operating their own equipment	5.1.5	The System shall support non-incident operation by multiple jurisdictions.						
5.2.2	SMCHub will serve as local agency control point during normal operations and as backup for the Caltrans TMC	5.1.4	The System shall support operation by multiple concurrent users/operators						
		5.1.6	The System shall allow a hierarchy of users.						

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5.2.3	Cameras will be accessible for control and viewing by all agencies	5.1.4	The System shall support operation by multiple concurrent users/operators						
5.2.3	A control hierarchy will be established	5.1.6	The System shall allow a hierarchy of users.						
5.3	**Special Operational Considerations**								
5.3.1	Video images accessible to agencies	5.1.4	The System shall support operation by multiple concurrent users/operators						
5.3.1	Prohibit video recording		In HLR						
5.3.1	Block camera fields of view		In HLR						
5.3.2	Share joint control of cameras	5.1.4	The System shall support operation by multiple concurrent users/operators						
		5.1.5	The System shall support non-incident operation by multiple jurisdictions.						
		5.4.1	Surveillance shall be used to help view the surface transportation system.						
5.3.3	Allow video use by public	Through Caltrans							
5.4	**Operations of Supporting Functions**								
5.4.1	Advanced At-grade crossing warning and coordination system	Future							
5.4.2	Provide bus location	Future							
5.4.2	Provide transit travel time Information	Future							
5.4.3	Provide arterial travel times	Future							
5.4.4	Overall system integration	5.1.3	The System shall be capable of interfacing with existing and planned ITS elements at all TMC levels.						
		5.1.8	The System shall be able to be expanded						
6.0	**Performance Measures**	5.1.17	The System shall be able to collect data that can be used to determine conformance with performance measures.						
	Percentage of incidents that do not require active traffic monitoring on local streets								
	Results of user surveys on the use of the Smart Corridor tools								
	Reduction in measured congestion								
	Reductions in system travel time								
	Reduction in queue clearance time								
	Reduction in amount of traffic filtering through the								

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	local network								
	Average time after an incident Caltrans notifies local agencies								
	Average time to deploy an alternate route								
	Average time required for traffic signals to transition to flush plan								
	Percentage of time that the use of Smart Corridor devices provides satisfactory traffic flow								
	Amount for sources expended for managing alternate route								