Santa Monica Freeway

SMART CORRIDOR

SMART CORRIDOR LESSONS LEARNED PROJECT

FINAL REPORT

Prepared for:

LOS ANGELES COUNTY
METROPOLITAN TRANSPORTATION AUTHORITY

Prepared by:

TRANSCORE
An SAIC Company

35 South Raymond Avenue
Suite 200
Pasadena, CA 91105

March 31, 1999

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LIST OF COMMON ABBREVIATIONS AND ACRONYMNS

AM	Amplitude Modulation
ATCS	Adaptive Traffic Control System
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Transportation Management Systems
ATSAC	Automated Traffic Surveillance and Control
CAD	Computer Aided Dispatch
Caltrans	California Department of Transportation
CATV	Community Access Television
CCTV	Closed Circuit Television
CHP	California Highway Patrol
CMS	Changeable Message Sign
COTS	Commercial-Off-The-Shelf
CPFF	Cost Plus Fixed Fee
DSS	Decision Support System
FFP	Firm Fixed Price
FHWA	Federal Highway Administration
FSP	Freeway Service Patrol
GUI	Graphical User Interface
HAR	Highway Advisory Radio
HAT	Highway Advisory Telephone
ITS	Intelligent Transportation Systems
LADOT	City of Los Angeles Department of Transportation
LAN	Local Area Network
MOE	Measures-of-Effectiveness
MOU	Memorandum-of-Understanding
MTA	Los Angeles County Metropolitan Transportation Authority
O&M	Operations and Maintenance
PCB	Professional Capacity Building
PS&E	Plans, Specification, and Estimates
SATMS	Semi-Automated Traffic Management System
SC	Smart Corridor
SCOPE	Smart Corridor Operations Planning Element
SCTC	Smart Corridor Technical Committee
SOW	Scope-of-Work
SR	State Route
T&M	Time and Materials
TCS	Traffic Control System
TMC	Transportation Management Center
TV	Television
WAN	Wide Area Network

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TransCore would like to recognize the contributions of the following agencies and firms in the development of this document.

Smart Corridor Agencies:

- Federal Highway Administration (FHWA)
- California Department of Transportation (Caltrans)
- California Highway Patrol (CHP)
- Los Angeles County Metropolitan Transportation Authority (MTA)
- City of Los Angeles Department of Transportation (LADOT)
- City of Beverly Hills
- City of Culver City
- City of Santa Monica

Firms:

- Gardner Transportation Systems
- Science Applications International Corporation (SAIC)

1. INTRODUCTION

1.1 LESSONS LEARNED PURPOSE

The I-10/Santa Monica Freeway Smart Corridor Demonstration Project is an innovative Intelligent Transportation Systems (ITS) project using advanced technologies to test the effectiveness of Advanced Transportation Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS) strategies. The fundamental objective of the Smart Corridor (SC) system is to maximize the efficiency and throughput of existing parallel freeway and arterial facilities throughout a 17-mile stretch of one of the most heavily traveled corridors in the nation. The system aspects of the Smart Corridor project comprise elements that are reflected in many ATMS and ATIS projects being deployed as part of the National ITS Program initiative. ITS is typically defined in the following manner:

> "The application of sensor, computer, electronics, and communications technologies and management strategies in an integrated manner; thereby providing traveler information to increase the safety and efficiency of the surface transportation system"

Because of its strategic importance to the advancement of ITS, the Smart Corridor project received a Federal Highway Administration (FHWA) grant designated specifically for the design and development of a central database and expert system. The FHWA funding agreement with the California Department of Transportation (Caltrans), and the Caltrans agreement with the Los Angeles County Metropolitan Transportation Authority (MTA), stipulates that the Smart Corridor project will include preparation of:

> "...a document which investigates the transferability of Smart Corridor technology to other locations and describes "lessons learned" during the systems design and development process..."

This "Lessons Learned" Report on the Smart Corridor system will address the complex decision-making processes that occurred during the development of the system configuration, hardware selection, software design, systems integration, and the adoption of operating policies. Its purpose is broader that just the transferability of the ENTIRE Smart Corridor concept. Conclusions will also be drawn regarding agency interactions, processes/procedures followed, and individual technical sub-components (e.g., CCTV, CMS, HAT, HAR, GUIs, SCOPE, central database, etc.). The "Lessons Learned " Report's ultimate goal is to identify factors that should be considered if components of the Smart Corridor are going to be transferred and replicated elsewhere. Its intent is to use personal investigative abilities to further the exposure and benefits of the Smart Corridor system in order to factually recognize this project as a key step in the further implementation of "smart corridors" nationwide.

1.2 LESSONS LEARNED OBJECTIVES

The core characteristics exhibited in the Smart Corridor project – multi-agency interaction, freeway/arterial integration, and real-time traveler information – are new operations for many public agencies and private sector firms. Such ITS stakeholders can benefit greatly from the experience gained by others from early ITS deployments. Applicable experience is often derived from carrying out an "Evaluation Study" aimed at measuring the system effectiveness and

benefits resulting from project execution. Such an evaluation study is currently being planned for the Smart Corridor and therefore, is not the focus of this document.

Basically, the primary objective within this lessons learned project was to "...retrieve the Smart Corridor experience...". There is tremendous benefit to be gained from understanding the experiences of the involved parties during the execution of the project. This is known as "Lessons Learned". The objective of a lessons learned exercise is to record and analyze the opinions, views, and experiences of the people involved in the project and derive recommendations and pointers which can be adopted to aid the successful execution of future projects, activities, and initiatives. Conducting a lessons learned exercise will go a long way to promoting the transferability of Smart Corridor technology to other locations and helping to prevent the same "mistakes" from being replicated elsewhere. In this manner, Smart Corridor can make a positive impact in the transportation industry and contribute greatly to improving future implementations of this nature.

As the previous section stated, this lessons learned document is more "institutional" in nature than "technical"; its focus is the complex decision-making processes, agency interactions, and personal experiences that occurred in Smart Corridor. Accordingly, the project approach was a qualitative process where the primary method for assessing the lessons learned was through in-depth interview and workshop sessions. Its intent is to use personal investigative abilities to further the exposure and benefits of the Smart Corridor system in order to factually recognize this project as a key step in the further implementation of "smart corridors" nationwide.

In order to minimize confusion regarding the contents of this document, the outline found in Exhibit 1.1 depicts what the report is going to cover as opposed to what it is not.

Covers	Does Not Cover

1. Analysis of the SC Experience
• Subjective evaluation
• Record people's individual opinions
	1. Evaluation
	• Objective analysis
	• Will not contain comprehensive factual data/information:
	  • How much SC cost?
	  • How well did SC perform?
	  • How well is SC designed?

2. Highlights of the most important SC facts and milestones • Just enough to provide background information to establish the appropriate context • Just enough to be able to "set-the-record-straight"	2. In-depth biography of SC
3. Technical Component Decision History • Why were certain decisions made? • What issues were involved? • What would we "do-again"?	3. In-depth technical analysis of individual components and systems
4. Pointers/Guidance • Best practices • Pitfalls-to-avoid • Mitigation measures	4. Guidelines • Design guidelines • Equipment selection/choice • Requirements development and selection • Functionality to include

Exhibit 1.1 – Lessons Learned Document Contents

1.3 LESSONS LEARNED STRUCTURE

The FHWA is actively promoting ITS deployment, and has developed a plan for ensuring that the national workforce is adequately prepared for the upcoming task. This effort is known as the Professional Capacity Building (PCB) program, and encompasses a plethora of training programs aimed at educating the public, practitioners in transportation, and elected officials in ITS. One of the courses in the PCB track – the "ITS Integration Course" – is targeted at transportation professionals and addresses the process of ITS deployment from planning all the way through to operations and management.

The ITS Integration Course uses "regional deployment" and "integration" as major themes of emphasis, and partitions the deployment process into a number of modules:

1. Short- and Long-Term Planning Needs
2. Stakeholders and Operational Objectives
3. Information Needs and Sharing
4. Operational Implications of Information Sharing
5. Design and Implementation Considerations
6. Procurement Strategies and Contracting Options
7. Operations and Management

Clearly, the ease-of-use of the Smart Corridor Lessons Learned Report is facilitated by structuring the document in such a manner that the resulting conclusions and recommendations relate readily to the real world of ITS deployment. This aspect is accomplished by adopting the PCB ITS Integration Course's module structure (above) as the basis for the interview questions, workshop exercises, and final report preparation.

1.4 DOCUMENT STRUCTURE

Following this brief introduction, the remainder of the Smart Corridor Lessons Learned Report is broken down into the following sections:

Section 2 – Smart Corridor Conceptual Overview. In this section, a Conceptual Overview of the Smart Corridor is presented that briefly describes (in lay terms) and graphically illustrates the Smart Corridor's systems, technical components, functionality, and operations.

Section 3 – Chronology of the Smart Corridor Development Process. This section presents a Project Chronology that covers the entire Smart Corridor timespan from its initial conceptualization to the current time period. In addition, a history of the Smart Corridor's contracts is presented in terms of contracting Agency, contract scope-of-work (SOW), and contract deliverables.

Section 4 – Lessons Learned Study Methodology. In this section, the study methodology that was used to develop this Lessons Learned report is presented in detail. Basically, the project approach was a qualitative process where the primary method for assessing the lessons learned was through in-depth interview and workshop sessions.

Section 5 – Lessons Learned: Agency Findings. This section presents a number of key findings obtained from the interview and workshop sessions. Findings are categorized into "Strengths" and "Weaknesses". In addition, the results of the "Interview Questionnaire" are presented.

Section 6 – Lessons Learned: Institutional Considerations. This section presents the key "lessons learned" obtained from the interview and workshop sessions. The findings are from an institutional issues outlook and categorized into the PCB Program structure (as described in Section 1.3). Key insights into what could make a Smart Corridor experience "better" are described and some Project Team "derived" recommendations presented.

Section 7 – Lessons Learned: Technical Considerations. In this section, the workshop findings that involve the Smart Corridor's technical issues are presented. The findings are structured along the lines of the Smart Corridor system components. Key insights into what could make a Smart Corridor experience "better" are described and some Project Team "derived" recommendations presented.

Section 8 – Lessons Learned: Stakeholder Uses. This section presents a number of actions that the Smart Corridor stakeholders are already putting into practice in their current day-to-day activities as a result of their own experiences in participating in the Smart Corridor project.

Appendices A–F: Smart Corridor Perspectives. In these appendices, all of the findings obtained from the interview and workshop sessions are presented in detail. Findings are categorized into "Strengths, "Weaknesses", and "Minority Opinions". Then, with all of these findings in-hand, a comparison can be made to determine how different Smart Corridor stakeholders viewed the same situations.

- Appendix A – Universal Themes
- Appendix B – Federal/State Perspective
- Appendix C – Regional Perspective
- Appendix D – Local Perspective
- Appendix E – Consultant Perspective
- Appendix F – Technical Considerations Perspective

2. SMART CORRIDOR CONCEPTUAL OVERVIEW

2.1 INTRODUCTION

In this section, a Conceptual Overview of the Smart Corridor is presented that briefly describes (in lay terms) and graphically illustrates the Smart Corridor's systems, technical components, functionality, and operations.

2.2 SMART CORRIDOR AGENCIES

The key Agency stakeholders involved in the design, development, and implementation of the Smart Corridor system are as follows:

- Federal/State Stakeholders
  - Federal Highway Administration (FHWA)
  - California Department of Transportation (Caltrans)
  - California Highway Patrol (CHP)
- Regional Stakeholders
  - Los Angeles County Metropolitan Transportation Authority (MTA)
  - Smart Corridor Technical Committee (SCTC)
- Local Stakeholders
  - City of Los Angeles Department of Transportation (LADOT)
  - City of Beverly Hills
  - City of Culver City
  - City of Santa Monica
- Agency Consultant
  - TransCore (formerly JHK & Associates)

2.3 SMART CORRIDOR PROJECT BACKGROUND

The Santa Monica Freeway Smart Corridor Demonstration Project was originally conceived as a means of ensuring that the travelers in Los Angeles County could, on a daily basis, enjoy the temporary benefits derived from measures taken to mitigate against traffic congestion resulting from the 1984 Summer Olympic Games. During that two-week period, the Agencies responsible for traffic operations and management in the City of Los Angeles coordinated the use of their resources in a cooperative manner. The result was the management of traffic in real-time, on both freeways and arterials, while keeping the public informed of congestion and the location of traffic delays. In this manner, the motoring public could make informed decisions about trips and route choice so as to avoid contributing to the anticipated congestion.

The key agencies involved, Caltrans and the City of Los Angeles Department of Transportation (LADOT), initiated a Smart Corridor Conceptual Design Study to identify project elements which would contribute to the following goal:

> "To test technologically advanced methods of improving regional mobility on freeways and major parallel streets without incurring the dramatic environmental and economic costs associated with building new freeways and streets."

The Santa Monica Freeway, between I-405 to the west and SR/I-110 in downtown Los Angeles to the east, was chosen as a test site due, in part, to the availability of parallel arterials, existing traffic signal control elements on these arterials, and existing ITS-type infrastructure along the freeway. The Conceptual Design identified approx. 30 project elements which could be deployed as part of a broad-based, multi-agency program to achieve these program objectives:

- Operate the individual facilities in the Corridor at their maximum efficiency
- Balance traffic flow between the freeway and parallel surface streets
- Manage and disseminate motorist information

The vision emerged of the operating Agencies responding to congestion situations in a coordinated fashion, using a wide range of traffic management tools, techniques, and technologies at their disposal. At the heart of this coordinated approach is the Smart Corridor System; a network of computers supporting inter-agency communications, real-time data management, and decision support processes, linked to the Agency-owned traffic management and traveler information systems.

2.4 SMART CORRIDOR SYSTEM COMPONENTS

The Smart Corridor system is comprised of many technical components as illustrated in Exhibit 2.1. In addition, these systems are operated and maintained by the various Smart Corridor Agencies as depicted in Exhibit 2.2. The following sections present a brief description of the Smart Corridor system components in terms of their functionality, number of components, and operational use.

2.4.1 Data Collection

Freeway Detection

Data from 377 inductive loops (one loop per lane at half-mile intervals) are combined every 30 seconds by Caltrans' Semi-Automated Traffic Management System (SATMS) to provide running average traffic counts and average speed.

Freeway Incident Detection

SATMS has the ability to run a number of different incident detection algorithms. The Smart Corridor central system uses the output from the running algorithm to automatically generate incident reports for use by the expert system.

Arterial Detection

The City of Los Angeles's Automated Traffic Surveillance and Control (ATSAC) system uses loop detectors on the arterials in Los Angeles and Culver City to collect data on a once-per-second basis to derive vehicle counts, occupancies and speeds. 2220 of these are used in the

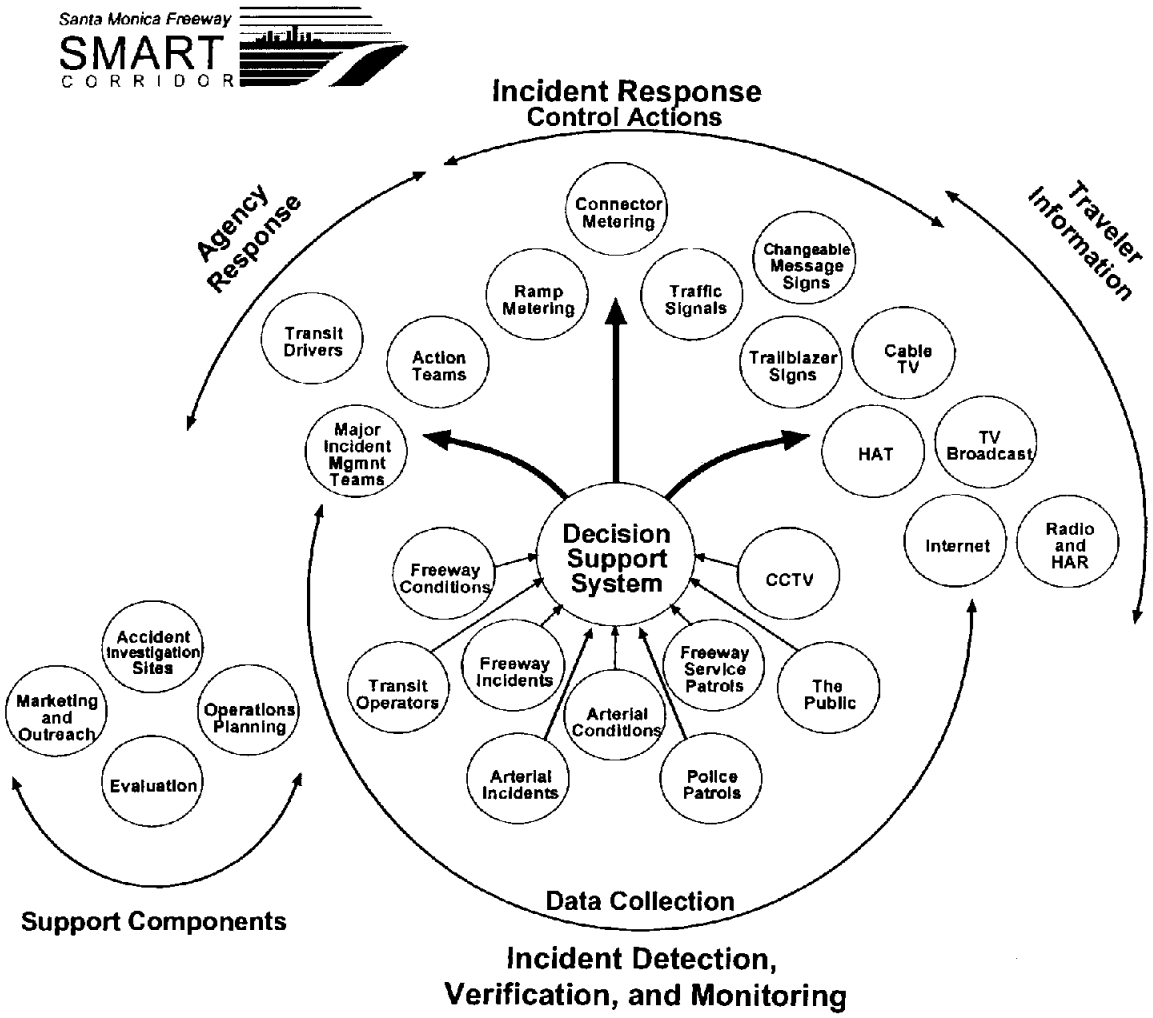

Exhibit 2.1 - Smart Corridor System Components

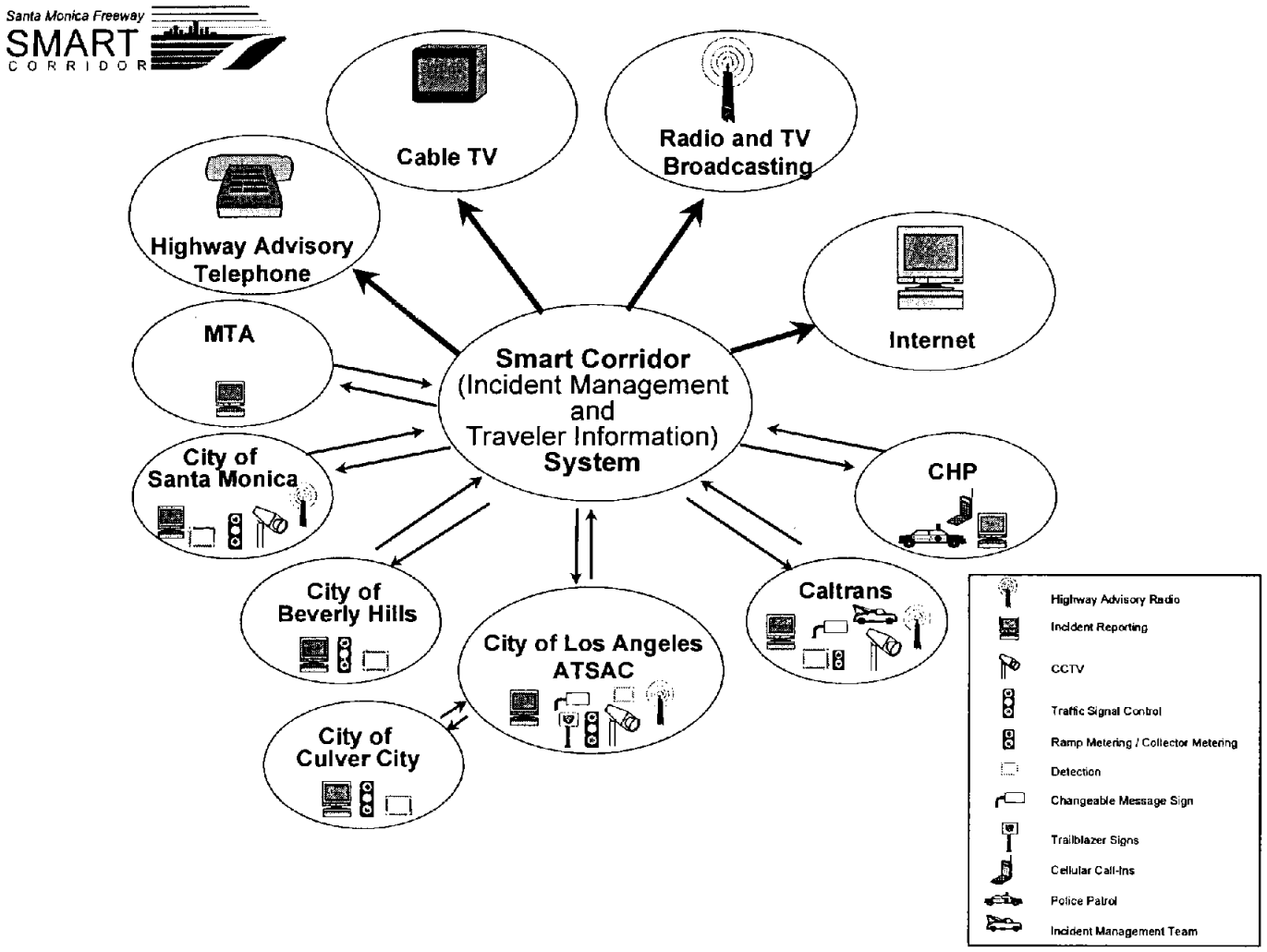

Exhibit 2.2 - The Agencies and Their Elements

Smart Corridor system. Traffic Control Systems (TCS) in the Cities of Beverly Hills and Santa Monica provide similar data.

Arterial Incident Detection

The Smart Corridor central system analyzes the incoming arterial data to identify incidents on the arterials and generate incident reports for use by the expert system.

CCTV Locations

Closed Circuit Television (CCTV) locations on both the freeway (13 cameras) and arterial road networks (38 cameras) are primarily used to verify incidents and check traffic conditions.

Cellular Call-In

The CHP answers cellular 911 calls and are able to input information provided by these calls into the Smart Corridor system for use by the expert system. However, this is not a direct process. Information from cellular 911 calls is first input into the CHP Computer Aided Dispatch (CAD) system. Then, either a CHP Officer at the Caltrans Transportation Management Center (TMC) or personnel at ATSAC enter this information into Smart Corridor.

Freeway Service Patrols (FSP)

These are motorist aid services provided by tow trucks that patrol the freeways during peak periods. The FSP drivers are in radio contact with operators at the Caltrans TMC who can input information into the Smart Corridor system for use by the expert system in decision making.

Response Teams

Both Caltrans and the City of Los Angeles operate teams that use special mobile equipment to deal with traffic problems associated with incidents. These teams are recognized by the Smart Corridor systems and recommendations for dispatch are made by the expert system, to the relevant Agency operator.

2.4.2 Control

Ramp Metering

The Smart Corridor system can select ramp meter rates at 86 ramp meter controllers to be used as response to freeway incidents.

Connector Metering

The Santa Monica Freeway/I-10 has junctions with the Harbor Freeway/SR-110 and the San Diego Freeway/I-405. Connectors between I-405 and I-10 and between SR-110 and I-10 can be controlled (metered) using above-the-lane signals as connector meters.

Traffic Signals

The Smart Corridor system can select signal-timing plans at 646 intersections to be implemented on the arterials as part of responses to incidents.

2.4.3 Information Dissemination

Changeable Message Signs (CMS)

CMS are located on both the freeways (8 signs) and City of Los Angeles arterials (5 signs) for the purpose of conveying information to drivers. These signs are "full matrix" type CMS that allow a variety of messages to be generated and displayed. The arterial CMS also support graphical displays.

Trailblazer (Diversion Signs)

In addition to the full matrix CMS, there are located on the arterials within the City of Los Angeles 14 dynamic signs which display alternate routes to the I-10 freeway. These are known as trailblazers and are used to implement diversion routing as part of an incident response.

Highway Advisory Radio (HAR)

HAR enables traffic reports to be broadcast within the corridor over dedicated radio channels on the AM waveband band. Unlike previous HAR installations, which rely on operators recording messages, in the Smart Corridor, the radio messages are automatically generated. Two types of HAR transmitters are included in the Smart Corridor project. HAR transmitters with powers in the 10 to 20 watt range are operated by Caltrans and the City of Santa Monica (one each) at 1610 AM. The City of Los Angeles has experimented with an innovative 0.1-watt (low-power HAR) approach using multiple, synchronized, transmitters arranged in cells that operate at 1640 AM.

Highway Advisory Telephone (HAT)

HAT enables access to real-time congestion and incident information (freeway and arterial) by both cellular and landline telephone. This makes HAT suitable for both pre-trip planning and en-route information. As with the HAR, the information is generated in an automated fashion without the need for an operator to record messages. Menu selections permit the caller to choose between incidents and congestion and to choose the section of arterial or freeway.

Internet

Smart Corridor is in the process of establishing an external Internet interface that will enable access to congestion and incident information via the World Wide Web. The web pages are to be hosted by Caltrans and the City of Los Angeles Department of Transportation.

Cable TV

Real-time graphical displays of freeway speeds are broadcast on public access Channel 35 in the City of Los Angeles during the morning and evening peak hours.

Media Terminals

Over twenty radio and television stations and private distributors of traffic information have access to Caltrans freeway data displayed on graphics screens via dedicated lines to Caltrans District 7. The screens have been augmented under the Smart Corridor project to include more detailed information on congestion and incidents in the Smart Corridor project area.

2.4.4 System

The Smart Corridor system comprises the following key elements:

Interfaces to agency systems for the collection of data and issuing of commands

These interfaces allow significantly different legacy interfaces to transfer real-time data using a common protocol on the Smart Corridor local and wide area networks. The interfaces also pass control commands to the legacy systems as part of incident responses.

A Shared Central Depository for Data

At the heart of the Smart Corridor lies a relational database in which is stored all of the configuration data for the system, including: the arterial and freeway link-node network, signal timing plans, ramp meter rates, CMS messages, CCTV presets, and incident response plans. The real-time data collected from the legacy systems is also held in this database which supports the graphical user interfaces used by the Smart Corridor operators.

An Expert System for Operator Decision Support

Starting with the indication that there may be an incident in the network, the Smart Corridor's expert system for operator decision support correlates the incoming incident reports from all sources, creates a profile of the incident, and presents it to the Smart Corridor operator for confirmation. Following confirmation using rules developed by the Agencies, the expert system derives a response plan that can use any or all of the various system components to mitigate the impact of the incident. In doing this, the expert system uses a navigable link-node model of the network to relate control elements with the incident location. The response plan is presented to the operator for approval. If approved, the expert system implements the response plan and monitors the incident situation, recommending changes as needed until the traffic impacts of the incident are cleared.

Graphical User Interfaces (GUIs) for input and display of real-time data

Smart Corridor operators access the Smart Corridor system through a common, window-oriented GUI. Operational functions and features can be accessed directly through the geographically correct map of the corridor. For example, reports on equipment status, or screens offering control of a CCTV camera are accessed simply be clicking on the device in question. In addition, system data are presented to the operator on screens organized in a "notebook" paradigm. As an example, when managing an incident, the screens or windows which the operator is using (typically: incident summary, incident report, CCTV control, response plan) are pages in the notebook, and the operator can "tab" from one page to another. The interface also supports video displays integrated into the CCTV control windows.

High-speed local and wide area networks (LANs and WANs) for the distribution of data and the linking of system components

Linking the various components of the Smart Corridor system is an Ethernet-based communications network. This takes the form of local area networks within the agency control centers, and connects these LAN's using links to other control centers.

3. CHRONOLOGY OF THE SMART CORRIDOR DEVELOPMENT PROCESS

3.1 INTRODUCTION

This section presents a Project Chronology that covers the entire Smart Corridor timespan from its initial conceptualization to the current time period. This brief chronology/milestone index of the Smart Corridor project is presented in Exhibit 3.1. In addition, a history of the Smart Corridor's system deployment contracts is presented.

3.2 SMART CORRIDOR CONTRACTS

Exhibit 3.2 presents a history of the prime contracts associated with the deployment of the Smart Corridor system. (Please note that Exhibit 3.2 does not list the Smart Corridor system's ITS-type field infrastructure installation contracts.)

Date	Event
December 1988	Smart Corridor Conceptual Design Study Started
August 1989	Smart Corridor Conceptual Design Study Completed
July 1990	Smart Corridor System Manager Contract Started
January 1991	Smart Corridor Preliminary Design Completed
January 1992	Smart Corridor Final Design Completed
May 1992	City of Beverly Hills Council Approves Involvement in Smart Corridor
May 1993	LADOT Operations Study (SCOPE) Started
May 1993	City of Culver City Signals under ATSAC Control
August 1993	City of Santa Monica Feasibility Study Started
March 1995	Caltrans SCEMIS Project Started
October 1995	City of Culver City Smart Corridor Extension Started
October 1995	City of Santa Monica Smart Corridor Extension Started
January 1996	Phase 1 Acceptance Testing
August 1996	SC Equipment Installation Complete in the ATSAC Control Center (SC Operational)
October 1996	Opening Ceremony
December 1996	City of Beverly Hills Olympic Signals under ATSAC Control
June 1997	Phase 2 Acceptance Testing
November 1997	LADOT Operations Study (SCOPE) Completed
February 1998	SCEMIS Acceptance Testing (Phase1)
May 1998	City of Beverly Hills Smart Corridor Workstation Installed
August 1998	City of Culver City Smart Corridor Workstation Installed
August 1998	CHP Smart Corridor Workstation Installed
August 1998	MTA Smart Corridor Workstation Installed
September 1998	SCEMIS Acceptance Testing (Phase 2)
September 1998	SC Equipment Installation Complete in the Caltrans TMC (SC Operational)
October 1998	Smart Corridor Operational
June 1999	City of Santa Monica Smart Corridor Workstations Installed

Exhibit 3.1 - Smart Corridor Chronology/Milestone Index

Contract	Lead Agency
Smart Corridor Conceptual Design Study	LADOT
Smart Corridor System Manager	MTA
Smart Corridor Operations Planning Element (SCOPE)	LADOT
Smart Corridor Enhanced Motorist Information Systems (SCEMIS)	Caltrans (District 7)
Westside Signal System Study	MTA
Santa Monica Smart Corridor Study	City of Santa Monica
Santa Monica Smart Corridor Extension	City of Santa Monica
Beverly Hills Olympic Project	City of Beverly Hills
Beverly Hills Wilshire Corridor Project	City of Beverly Hills
Culver City Smart Corridor Extension	City of Culver City

Exhibit 3.2 - Smart Corridor System Deployment Contracts

In the sections that follow, more detail is presented for each of these contracts in terms of contracting Agency, contract SOW, contract type, and contract deliverables.

Contract	SC Conceptual Design Study	
Contracting Agency	LADOT	
Contract Type	Costs Plus Fixed Fee (CPFF)	
Key Project Task	**Description**	**Deliverables**
Investigate Project Elements	• Identify Project Elements for consideration as part of the Smart Corridor Project • Describe the elements, deployment and operational issues, and how they would be applied in the Smart Corridor	Project Workbook
Derive a Conceptual Design	Derive an overall approach for the Smart Corridor system, identifying components, their location, and their inter-operation.	Final Report
Define an Implementation Plan	For the components chosen to be part of the Smart Corridor, identify a deployment schedule, responsibilities for deployment, and capital and operational costs.	SC Implementation Plan

Contract	SC System Manager	
Contracting Agency	MTA	
Contract Type	Costs Plus Fixed Fee (CPFF)	
Key Project Task	**Description**	**Deliverables**
Preliminary Design	Develop a Preliminary Design for the Smart Corridor System to include: • Definition of System Functionality • Analysis of Software Platforms • Analysis of Hardware Platforms • System Configuration • Location of Field Equipment	Preliminary Design Report
Central Data Base and Expert Systems	Design and implement the central system software for the Smart Corridor system	• System Software Design • Data Base Server Specification • Expert System Design Specification • System Software Development
CCTV Element	Design the arterial CCTV system	CCTV System Specification Report
Highway Advisory Radio (HAR) Element	• Investigate the feasibility of low power HAR for the arterial application • Develop a design for the Freeway HAR	• Evaluation of Low Power HAR • P.S. & E. for Freeway HAR
Changeable Message Sign (CMS) Element	• Analyze technology alternatives for full matrix and trailblazer type arterial signs • Develop designs for their implementation • Design and develop CMS control software (central and field)	• Report on Trailblazer Sign Alternatives • P.S. & E. for Surface Street Full Matrix CMS • Trailblazer Specification • CMS control software • Ledstar Sign Inspection Report
Control Center Linkages	Design and implement the Smart Corridor LAN and WAN	• Communications Network Report • Installed network
System Integration	Integrate the Smart Corridor System Software with the legacy systems, the CCTV system, and the CMS	• Acceptance Test Procedure • Integrated System
Technical Services	Provide documentation, training, and post-installation support	• Database Specification • GUI User's Manual • Administrative Guide for Administrative Screens and Map Editing • Agency Interface • Developer's Guide • Operations and Maintenance Manual • Reports User's Reference • System Description
ATSAC System	Contract extension to carry out Smart Corridor related work on the ATSAC system • Design of a seven-projector display system • Analysis of options for improved field communications equipment • Enhancements to the ATSAC graphical displays	• P.S. & E. for Projection System • Evaluation of VMEBus Intelligent Serial Controllers for the ATSAC PPU Graphics Enhancements

Contract	SC Operations Planning Element (SCOPE)	
Contracting Agency	LADOT	
Contract Type	Firm Fixed Price (FFP)	
Key Project Task	**Description**	**Deliverables**
Analysis of Incidents	Document and analyze the characteristics of incidents on the Santa Monica freeway	• Incident Data Base • Corridor-Wide Incident Summary • Existing Traffic Conditions Report • Analysis of Incidents Report
Analysis of Existing Operational Practices	• Document current operational practices in the SC Agencies (MTA/LADOT/Caltrans/CHP) • Identify deficiencies with respect to Smart Corridor and inter-Agency operations	• Documentation Review • Identification of Current Practices • Existing Operational Strategies Report
Modeling	Use a traffic model to analyze the impact of incidents in the corridor, and possible response actions	• Link-Node Model • CORFLO Model • Report on Lessons Learned from the Trial of the CORFLO Model
Policy Development	Development of Operational Policies for traffic control and route guidance and information dissemination	• Presentations • Operations Policy Statement
Develop Operational Procedures	Development of Operational and Inter-Agency Procedures for the Smart Corridor system	Standard Operating Procedures Manual
Incident Identification and Responses	• Development of methods to identify and respond to incidents • Development of the process of responding to incidents	Process of Incident Response Plan Development
Knowledge Base Design	Development of the design for the knowledge base (KB) of the Expert System (Nexpert Object)	• KB Classes and Attributes • KB Data Structures and Methodologies
Design and Development of an Incident Management System	Design and implementation of the specific SC incident detection application	• Design Document • Arterial Incident Detection Algorithm • Multi-Operator Support Software • Response Plan Editor • Response Plan Approval and Implementation Software
Development of Incident Response Data Base	Implementation of the rules for responding to incidents in the Expert System	• Preliminary Rule Set • Incident Scenarios • Final Rule Set
Implement and Test	Implementation and test of the full Smart Corridor system	• Completed Acceptance Tests • Operating Instructions
Training	Provide staff training	Training Course
Technical Support	Provide technical support	Technical Support

Contract	SC Enhanced Motorist Information Systems (SCEMIS)	
Contracting Agency:	Caltrans District 7	
Contract Type:	Costs Plus Fixed Fee (CPFF)	
Key Project Task	**Description**	**Deliverables**
System Design	Develop a system design for the addition of motorist information systems to the base Smart Corridor system	System Design Report
Equipment Procurement	Identify and procure the necessary equipment	Equipment
Highway Advisory Telephone (HAT) System Development	Develop HAT and SC-specific software for the automated provision of real-time incident and congestion information by telephone	Automated HAT system
Freeway Advisory Radio Message (FAR) Generation System	Develop an interface between the HAT and the FAR to enable the automated broadcast of real-time incident information	HAT/FAR software
Surface Street Advisory Radio Message (SSAR) Generation System	Develop an interface between the HAT and the SSAR to enable the automated broadcast of real-time incident information	HAT/SSAR software (not implemented)
Transfer of Planned Event Information from the Caltrans System	Develop an interface between the SC system and the Caltrans event database for the input of maintenance and closure information	SC interface software
Transfer of Smart Corridor Motorist Advisories to the Caltrans Media Interface System	Develop a means to enhance the Caltrans Traffic Vision system with additional real-time information regarding incidents and congestion in the Smart Corridor	SC interface software and upgraded Media Interface System
Traffic Vision Graphical Display Modifications	Modify the graphical displays currently used by the media (e.g., radio, TV, traffic services, etc.) to accommodate more detail in the SC area	Modified PC graphics software
Smart Corridor System Modifications	Improve aspects of the Smart Corridor GUI	Modified GUI
CCTV Integration	Integrate the ATSAC and Caltrans CCTV systems to permit the seamless control of cameras and display of video images at the SC workstations	Upgraded SC workstation software
Installation Supervisor	Supervise the execution of any related contract activities	
On-Site Integration and Test	• Develop Acceptance Test Schedules • Carry out acceptance testing on the SC Motorist Information Systems	Signed Acceptance Test Schedules
Training	Provide on-site training on the new SC systems	Training courses
Documentation	Amend existing SC documentation and develop new documentation	• Standard Operating Procedures • Operator Interface Manual • Systems Description • Database Specification • Media Interface System: •Media Server Reference Manual •Traffic Vision User's Manual •CCTV Reference Manual

Contract	Westside Signal System Study	
Contracting Agency	MTA	
Contract Type	Firm Fixed Price (FFP)	
Key Project Task	**Description**	**Deliverables**
Problem Analysis	Study options available for incorporating traffic signal controlled intersections on Olympic Boulevard within the City of Beverly Hills into the Smart Corridor project	Westside Signal System Interface Study

Contract	Santa Monica Smart Corridor Study	
Contracting Agency	City of Santa Monica	
Contract Type	Costs Plus Fixed Fee (CPFF)	
Key Project Task	**Description**	**Deliverables**
Problem Analysis	Analysis of traffic conditions in the City of Santa Monica and potential benefits of extending the Smart Corridor System	• Inventory of Existing Equipment • Problem Analysis Report
Alternatives Analysis	• Analysis of technologies and solutions to address the identified problems • Selection of recommended approach	Smart Corridor Operations Report
Implementation Plan	• Develop a plan for extending the Smart Corridor to the Pacific Coast Highway • Identify a system configuration, field devices and their locations, and estimated costs for installation, operations, and maintenance	Smart Corridor Extension Deployment Analysis and Implementation Plan

Contract	Santa Monica Smart Corridor Extension	
Contracting Agency	City of Santa Monica	
Contract Type	Firm Fixed Price (FFP)	
Key Project Task	**Description**	**Deliverables**
Systems Design	Prepare a detailed design of the extension to the Smart Corridor system along I-10 from Pacific Coast Highway to I-405	System Design Report
Systems Development	Develop and integrate software and systems commensurate with the System Design	• Specification for Smart Corridor/Arterial Master Interface Server • Acceptance Test Plan • Training Course • System Documentation • SC Workstations • Econolite Command/Data Interface
Field Design	Prepare the following designs: • Signal controller upgrades • Communications • System detectors • HAR • CCTV • TMC layout	• Cabinet Replacement Sketches • Communications Plans • Communications Facility List • System Detector Plans • HAR Plan • CCTV Plan • TMC Specifications

Contract	Beverly Hills Olympic Project	
Contracting Agency	City of Beverly Hills	
Contract Type	Firm Fixed Price (FFP)	
Key Project Task	**Description**	**Deliverables**
System Design	• Develop a design to incorporate the signals located on Olympic Blvd. into the Smart Corridor system • Accommodate the City of Beverly Hills as a Smart Corridor Agency	Design Report
Implement the System Design	• Bring the Olympic Blvd. Intersections under the control of the ATSAC system • Install a SC workstation in Beverly Hills • Modify SC system to recognize Beverly Hills as an Agency	Modified SC GUI screens

Contract	Beverly Hills Wilshire Corridor Project	
Contracting Agency	City of Beverly Hills	
Contract Type	Firm Fixed Price (FFP)	
Key Project Task	**Description**	**Deliverables**
System Configuration	• Develop a system design for a traffic signal system for the City of Beverly Hills which will interface with the SC system as a second arterial system • Exchange traffic signal data with the ATSAC system for improved inter-jurisdictional coordination	System Design Report
Implementation and Test	Install the traffic control system and integrate with the SC system	Installed System
Documentation and Training	Document the installed system and train City staff	• Documentation • Training Courses

Contract	Culver City Smart Corridor Extension	
Contracting Agency	City of Culver City	
Contract Type	Costs Plus Fixed Fee (CPFF)	
Key Project Task	**Description**	**Deliverables**
System Design	• Develop a design for the installation of a Smart Corridor workstation at the City of Culver City's City Hall • Design a communications link from ATSAC to Culver City	• Design Report • P.S. & E. for the communication equipment
Implement the Design	• Procure communications equipment, workstation, and software • Install the equipment and test	Operational Smart Corridor workstation at Culver City

4. LESSONS LEARNED STUDY METHODOLOGY

4.1 INTRODUCTION

In this section, the study methodology that was used to develop this Lessons Learned report is presented in detail. Basically, the project approach was a qualitative process where the primary method for assessing the lessons learned was through in-depth interview and workshop sessions. Overall, the general services performed included the following at a minimum:

- Development of a list of interview questions
- Development of a list of candidates to interview
- Finalization of the overall work plan and schedule
- Preparation of a Project Chronology and Conceptual Overview
- Performance of "one-on-one" interviews and group workshops
- Development of interview and workshop summaries
- Preparation of a Draft, Revised Draft, and Final "Lessons Learned" Report

4.2 LESSONS LEARNED PROJECT APPROACH

In order to successfully develop this Report, the selected project approach was primarily a qualitative analysis of the Smart Corridor experience. The primary method for assessing the lessons learned was through an in-depth interview process conducted at three (3) levels:

- "One-on-One" interviews with Smart Corridor Agency participants
- Individual Agency Workshops
- SCTC Workshop

Key past and present participants associated with the Smart Corridor project were subjectively interviewed for their observations and individual opinions concerning its technical components, development process, institutional relationships, and project administration.

The following paragraphs highlight the key SOW aspects that were undertaken within this project:

4.2.1 Task 1 – Finalize Interview Questions, Schedule, and Overall Work Plan

The 1st step within this task was to develop a task level SOW and schedule detailing the entire work effort to provide an initial indication of the project's intended direction in order to avoid any potential pitfalls. The 2nd step was to prepare a "List of Interview Participants"; a representative set of key individuals (both current and former employees) involved in the project from each of the Smart Corridor Agencies:

- Federal/State Perspective
  - FHWA
  - Caltrans

    - CHP
- Regional Perspective
    - MTA
    - SCTC
- Local Perspective
    - LADOT
    - City of Beverly Hills
    - City of Culver City
    - City of Santa Monica
- Consultant Perspective
    - TransCore

The final step within Task 1 was to develop a "List of Interview Questions" that address the complex decision-making processes that occurred during the development of the overall system configuration, hardware selection, software design, system integration, and the adoption of operating policies. These questions formed the basis of the interview and workshop sessions (conducted in Task 3). The ultimate goal of these questions was to identify factors that should be considered if components of the Smart Corridor are going to be replicated elsewhere. The questions were structured along the lines of the FHWA's PCB ITS Integration Course's module structure (Section 1.3). Initially, the TransCore Team conducted a brainstorming session that resulted in a "draft" set of questions being developed. Key members of the SCTC then reviewed this list. A joint discussion between TransCore and the SCTC generated additional questions, deleted questions that were felt to be "out-of-scope", and then prioritized the questions in order to focus the interview and workshop sessions. The "final" list of questions can be found in Appendix G. The prioritized list can be found in Appendix H.

4.2.2 Task 2 – Prepare Conceptual Overview and Chronology

Within Task 2, a Conceptual Overview of Smart Corridor was prepared that briefly describes (in lay terms) and graphically illustrates the Smart Corridor's components and operations. In conjunction with this effort, a Project Chronology was developed that covers the entire Smart Corridor timespan from its initial conceptualization to the current time period. In order to accomplish this Task, pertinent Smart Corridor program documentation and contracts were reviewed in detail and topics for inclusion developed and prioritized during a brainstorming session. Key highlights in the following areas were incorporated:

- Project Background
- System Components
- System Functionality
- Contracts
- Major Project Milestones

Both the Conceptual Overview and Project Chronology are extremely useful tools because they allow everyone involved in the project to be "on-the-same-page" in their understanding of the Smart Corridor system's history, components, and operations.

4.2.3 Task 3 – Conduct Interview and Workshop Sessions

Basically, the primary objective within Task 3 is to "...retrieve the Smart Corridor experience...". Lessons Learned were obtained through an in-depth interview process conducted at three (3) levels:

- "One-on-One" interviews with Smart Corridor Agency participants
- Individual Agency Workshops
- SCTC Workshop

Key past and present participants associated with the Smart Corridor project (from system operator to upper management) were interviewed for their observations concerning its technical components, development process, institutional relationships, and project administration. In this manner, a high-level management, technical staff, and system operator perspectives were identified. In addition, this approach ensured that every individual was heard; not just that a one-sided perspective was obtained.

The one-on-one interview methodology focuses on "how" to retrieve the Smart Corridor experience as described in the following steps:

1. Send List of Interview Questions (Task 1), Conceptual Overview (Task 2), and Project Chronology (Task 2) to participants two (2) weeks prior to their scheduled interview
2. Interview participant is asked to answer ALL questions and "highlight" questions that they would like to discuss in the interview
3. One-on-one interviews (approx. 60 minutes) are conducted using prioritized questions and participants' highlights

To complement these individual interview sessions, Smart Corridor Agency group workshops were conducted as follows:

- Caltrans Workshop
- LADOT Workshop
- Local Agencies Workshop (Beverly Hills, Santa Monica, Culver City)
- SCTC Workshop (Representatives from every Smart Corridor Agency)

Agency workshops were held separately with as many interview participants in attendance as possible. Independent and unbiased representatives acted as the Workshop Facilitators in order to provide participants with the opportunity to speak in an "open" environment with guaranteed anonymity. Workshop participants were led through a series of roundtable discussions on technical considerations and key areas identified within the one-on-one interviews. These workshops were intended to accomplish the following:

- Build a consensus perspective for each agency in order to ascertain "how" they viewed a particular situation/issue/event
- Verify interview findings/issues for validity
- Clarify comments/responses from the interview sessions
- Address issues concerning Smart Corridor's technical components
- Allow a first-hand exchange of ideas/opinions to be shared between members of the same Agency and amongst the various participating agencies (SCTC Workshop)
- Ascertain which areas are of utmost importance to the participating agencies in order to reflect these priorities within the "DRAFT" and "FINAL" Reports.

Following conduct of the interview and workshop sessions, summary findings were prepared in the following fashion:

- Broken down into the Agency perspectives (as identified in Task 1)
- Separate technical considerations developed
- Categorized by the FHWA's PCB ITS Integration Course's module structure (as identified in Section 1.3)
- Universal Themes
- Smart Corridor "Strengths"
- Smart Corridor "Weaknesses"
- Minority Opinions

Then, with all of the interview and workshop sessions and summary findings completed, a comparison can be made to determine how different Smart Corridor Agencies viewed the same situation.

4.2.4 Tasks 4, 5, & 6 – Prepare Smart Corridor Lessons Learned Report

Basically, the objective of these three (3) tasks is to develop the Lessons Learned Report that you are now reading. In order to accomplish this endeavor, the step-by-step approach used by the Project Team is outlined below:

TASK 4 – PREPARE "DRAFT" REPORT

1. Review Task 2 deliverables
2. Compile Task 3 Summary Findings
3. Develop "DRAFT" Report Outline
4. Analyze findings from Step #'s 1 and 2 (above)
   - Develop Smart Corridor conclusions
   - Develop derived recommendations (or lessons learned)
   - Summarize questionnaire results
5. Develop "DRAFT" Report

- Represents a breakdown of the resultant opinions, observations, and experiences
- Highlighted questions and workshop priorities (from Task 3) form the basis for the "DRAFT" Report's "order" as they reflect Agency priorities

TASK 5 – PREPARE REVISED "DRAFT" REPORT

1. Present "DRAFT" Report to the Smart Corridor Agencies for review
   - Allow an opportunity to obtain concurrence from the participating Agencies that the facts are correctly presented
   - Provide corrections and "feedback" to the Team in written form
2. Review comments/feedback
3. Undertake "additional" interviews and/or work effort (as necessary)
4. Come to consensus on what items are to be included within Revised Draft Report
5. Incorporate comments
   - Any outstanding comments are communicated to the participating individuals for their consideration on whether they would want to provide a "minority opinion" addendum to the Final Report
   - This could be provided if any project member did not agree on an important point forwarded by the Team
6. Develop Revised "DRAFT" Report

TASK 6 – PREPARE "FINAL" REPORT

1. Present Revised "DRAFT" Report to the Smart Corridor Agencies for review
   - Provide corrections and "feedback" to the Project Team
   - Request clarification on relevant findings/issues
2. Review comments/feedback
3. Come to consensus on what items are to be included within Final Report
4. Incorporate comments
5. Develop "FINAL" Report
6. Provide the "FINAL" Report in a web-ready format (both HTML or PDF)

5. LESSONS LEARNED: AGENCY FINDINGS

5.1 INTRODUCTION

This section presents a number of key findings obtained from the interview and workshop sessions. Findings are categorized into "Strengths" and "Weaknesses". In addition, the results of the "Interview Questionnaire" are presented.

5.2 SMART CORRDIOR CONCLUSIONS

The following conclusions were derived from the comments made by, and input received from the interview and workshop participants.

5.2.1 Strengths

1. **Inter-Agency Coordination and Cooperation**. In working together, mutual trust and respect were achieved among Agencies with previously uncoordinated agendas for traffic management within the corridor. Agencies learned to regard the whole transportation system as a shared responsibility for a more effective product at a better price. Agencies also learned about how their individual actions may impact another Agency.
2. **Knowledge Gained through Technical Accomplishments**. Most interviewees believe that great technical accomplishments have been made on SC, and that much valuable knowledge has been gained through the program. Many believe that the technical accomplishments resulted in a system that is the most advanced of its type in the world.
3. **Individual Commitment and Dedication**. Many interviewees cited the strong personal commitment and dedication of many individuals as a strength of the SC program. Enthusiasm of the individuals involved in the program maintained momentum throughout the project's duration. Persons with a great deal of devotion and passion for the concepts supported the program tirelessly in order to make great strides.

5.2.2 Weaknesses

1. **Staff Turnover**. Turnover, both at TransCore, and at the Agencies, impacted the project as corporate/agency "memory" was lost whenever a project member left. When new people were brought in, each had to tackle a significant learning curve. Often, new staff did not have the detailed knowledge of prior decision-making, so they tended to want to "re-invent" the issues/decisions previously made.
2. **Demonstration System vs. Operational System.** Differing opinions exist, both within and across Agencies and TransCore, as to whether the SC system should be a demonstration system, an operational system, a demonstration of an operational system, or an operational system to demonstrate concepts. Many Agency "differences-of-opinions" stem from the fact that various perspectives exist as to what are acceptable performance requirements for the system.
3. **An Ambitious and Complex Undertaking.** In retrospect, the scope of the SC program was overly ambitious considering the technology available at the time, and the resulting system took too long to develop. Both TransCore as well as the Agencies underestimated the complexity and the schedule/time that it would actually take to complete.

4. **Requirements Issues Were Pervasive.** It is clear that many of SC's perceived weaknesses stem from requirement issues. Requirement expectations unfolded and were either not articulated, or not captured, or both. For example, performance requirements were not addressed in relation to a robust, reliable system. Requirements were not clearly documented, baselined, or managed for changes. This situation often caused a requirement to not be understood in the same manner by all involved stakeholders.

   Explanatory Note: *The Smart Corridor program spans two (2) eras of transportation system design philosophy. It has its roots in the "traditional" engineering approach represented by carrying out a Conceptual Design Study, followed by a Preliminary Design Phase, and then a Detailed Design Phase. The outputs of these phases are characterized by wordy documents that are descriptive in nature. While providing a good narrative format that transportation engineering professionals are familiar, this approach is not suited to meet the need to precisely convey the desired system functionality to the system developer.*

   The deficiencies of this approach have been recognized, and there is consensus that more attention needs to be given to adopting a stricter "Systems Engineering" approach to system design and development. This approach lays great emphasis on the definition of Functions and Requirements; whereas a function describes "what" a system must do and requirement describes "how well" the function must be performed. The "Systems Engineering" approach uses a number of "shall" statements to succinctly describe it contents and is commonly broken down into concept-of-operations, user requirements, functional requirements, and detailed design phases.

   In the latter stages of the SC project, specifically the GUI development in the Phase 2 implementation and the re-start of the SCEMIS contract, specific efforts were made to establish clear definitions and requirements for the remaining work. Interviews with participants have remarked on the benefits of these actions.

5. **Impacts of "New" Technology".** The SC program was not structured to keep up with rapidly changing technology. The project spanned more than a decade, during which unforeseeable technical evolutions came about. Overall, the project was not structured with the flexibility to respond to changes in technology, and only in specific cases were appropriate corrective actions taken when alternative solutions or approaches became available.
6. **System Reliability.** The current SC system is not reliable and crashes frequently. The lack of reliability is preventing further evaluation and extension of the SC concept in its current form.
7. **Risk Mitigation.** Risk mitigation activities were only performed in the latter stages of the project by TransCore. The participants as a group did not consistently consider what things might go wrong or determine what strategies could be used to mediate those risks.

5.3 INTERVIEW QUESTIONNAIRE FINDINGS

5.3.1 Overview

Prior to conducting the interview and workshop sessions, an Interview Questionnaire package was sent to all identified Smart Corridor participants. A key component of this package was the "List of Interview Questions" (found in Appendix G). As stated previously, the interview/workshop questions were structured along the lines of the FHWA's PCB program's "ITS Integration Course" training modules. Although the questions were primarily qualitative in

nature, a number of questions were presented in a multiple-choice, value-oriented format in order to obtain some quantitative insight on the Smart Corridor lessons learned.

Overall, 55 questionnaires were distributed and 16 responses received. Since this only represents a 30% return rate, the quantitative values presented below should be viewed accordingly. (Further statistical breakdown of the responses was not pursued in order to guarantee the anonymity of the participants). In addition, preliminary conclusions regarding the responses are forwarded as appropriate.

5.3.2 Short- and Long-Term Planning Needs

1. Was the coordination between the Agencies for planning of the Smart Corridor aspects effective?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
6% or (1)	44% or (7)	31% or (5)	0%

Conclusion: **A majority believes that SC planning was effectively coordinated, but with room for improvement**

N/A: 19% or (3)

2. Would you change the way project planning was done between the Agencies?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
19% or (3)	37% or (6)	19% or (3)	6% or (1)

Conclusion: **A majority believes that project planning between the Agencies should be changed**

N/A: 19% or (3)

3. Is there a process in place for furthering Smart Corridor-type deployments in Los Angeles County?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
12.5% or (2)	25% or (4)	0%	12.5% or (2)

Conclusion: **A majority believes that a process for furthering SC-type projects exists in Los Angeles County**

N/A: 50% or (8)

5.3.3 Stakeholders and Operational Objectives

1. Do you believe that the Operational Objectives were articulated clearly?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
38% or (6)	31% or (5)	25% or (4)	0%

Conclusion: A majority believes that the Operational Objectives were clearly articulated

N/A: 6% or (1)

2. Do you believe that the Operational Objectives were understood and adopted by all of the Agencies and Team members?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
6% or (1)	44% or (7)	38% or (6)	6% or (1)

Conclusion: There was some understanding of Operational Objectives but some were not understood

N/A: 6% or (1)

3. Do you believe that the Operational Objectives have changed during the course of the project (i.e., from 1988 until today)?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
31% or (5)	25% or (4)	19% or (3)	19% or (3)

Conclusion: A majority believes that the Operational Objectives have changed during the course of the project

N/A: 6% or (1)

4. Would you change the Operational Objectives today if you were developing a new Smart Corridor system?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
12.5% or (2)	31% or (5)	44% or (7)	12.5% or (2)

Conclusion: A majority believes that they would not change the Operational Objectives

N/A: 0%

5. Was adequate staff available throughout the program?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
13% or (2)	31% or (5)	31% or (5)	25% or (4)

Conclusion: **A majority believes that adequate staff was not available throughout the project**

N/A: 0%

5.3.4 Information Needs and Sharing

1. Was the information sharing process/mechanism used between the Agencies effective?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
12.5% or (2)	44% or (7)	31% or (5)	0%

Conclusion: **A majority believes that information sharing was effective**

N/A: 12.5% or (2)

2. Has the level of cooperation between the Agencies improved?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
25% or (4)	50% or (8)	6% or (1)	6% or (1)

Conclusion: **A strong majority believes that Agency cooperation improved**

N/A: 13% or (2)

3. Was there any reluctance to share information?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
19% or (3)	12% or (2)	19% or (3)	31% or (5)

Conclusion: **A majority believes that there was no reluctance to share information**

N/A: 19% or (3)

5.3.5 Operational Implications of Information Sharing

1. Did a viable, coordinated concept-of-operations emerge from the project?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
19% or (3)	44% or (7)	12% or (2)	12% or (2)

Conclusion: A majority believes that a coordinated concept-of-operations emerged

NA: 13% or (2)

2. Did the Agencies clearly partition the areas of operational responsibility between them for Smart Corridor?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
56% or (9)	25% or (4)	6% or (1)	0%

Conclusion: A strong majority believes that operational responsibility was clearly partitioned

N/A: 13% or (2)

3. Do all member Agencies seem to agree on the partitioning of operational responsibilities?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
44% or (7)	50% or (8)	6% or (1)	0%

Conclusion: A strong majority believes that the Agencies agreed to this partitioning

N/A: 0%

4. Did the Agencies build and maintain consensus throughout the program's duration?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
19% or (3)	56% or (9)	19% or (3)	6% or (1)

Conclusion: A strong majority believes that Agency consensus was built/maintained

N/A: 0%

5.3.6 Design and Implementation Considerations

1. Were the methods used to design the system effective?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
0%	38% or (6)	44% or (7)	12% or (2)

Conclusion: **A majority believes that system design methods were not effective**

N/A: 6% or (1)

2. Were the original user requirements translated into design considerations?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
0%	63% or (10)	19% or (3)	6% or (1)

Conclusion: **A majority believes that to some extent user requirements were translated into design considerations**

N/A: 12% or (2)

3. Were any user requirement rejected due to their technical difficulties relative to benefit?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
31% or (5)	25% or (4)	13% or (2)	0%

Conclusion: **A majority believes that there was rejection of user requirements due to their technical difficulties relative to benefit**

N/A: 31% or (5)

4. Do you feel that any of the original design considerations were unrealistic?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
19% or (3)	25% or (4)	31% or (5)	19% or (3)

Conclusion: **A higher number of respondents felt that the design considerations were realistic**

N/A: 6% or (1)

5. If so, were these concerns voiced to the appropriate parties?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
19% or (3)	25% or (4)	12% or (2)	0%

Conclusion: Of those who felt that design considerations were unrealistic, the majority felt that concerns had been, to some extent, voiced

N/A: 44% or (7)

6. Has the advancement of technology during the life of Smart Corridor had an impact on the program?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
88% or (14)	12% or (2)	0%	0%

Conclusion: A strong majority believes that technology advancements had an impact on Smart Corridor

N/A: 0%

5.3.7 Procurement Strategies and Contracting Options

1. Did the Agencies have any contract regulations that they were required to follow?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
69% or (11)	12% or (2)	0%	0%

Conclusion: A strong majority believes that the Agencies had contract regulations to follow

N/A: 19% or (3)

2. Were the contracting methods used to procure and build the systems effective?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
12.5% or (2)	31% or (5)	19% or (3)	25% or (4)

Conclusion: A broad range of opinion existed towards the contracting methods used to procure Smart Corridor therefore no conclusions could be drawn

N/A: 12.5% or (2)

3. Were the contract type(s) appropriate, given what you have experienced?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
6% or (1)	31% or (5)	31% or (5)	19% or (3)

Conclusion: **There could have been improvement in the contracting efforts by matching contract type to scope of work**

N/A: 13% or (2)

4. Do you think that contact terms and conditions effectively managed the risk for the contracting Agencies?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
12% or (2)	38% or (6)	25% or (4)	6% or (1)

Conclusion: **A majority believes that the contract Terms and Conditions managed Agency risk, but that there was room for improvement**

N/A: 19% or (3)

5. Do you think that the contract terms and conditions placed an unreasonable burden on the Contractors/Consultants?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
19% or (3)	25% or (4)	31% or (5)	12.5% or (2)

Conclusion: **No conclusions could be drawn as to whether the contract Terms and Conditions placed an unreasonable burden on the Contractors/Consultants**

N/A: 12.5% or (2)

6. Were the original budget estimates realistic?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
0%	25% or (4)	19% or (3)	31% or (5)

Conclusion: **A majority believes that the budget estimates were not realistic**

N/A: 25% or (4)

5.3.8 Operations and Management

1. Were you satisfied with the development of the Smart Corridor Operational Procedure Element (SCOPE) process?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
6% or (1)	38% or (6)	19% or (3)	6% or (1)

Conclusion: A majority was satisfied with the development of the Smart Corridor Operation Procedure Element

N/A: 31% or (5)

2. Has operation of Smart Corridor elements proven to be satisfactory?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
0%	44% or (7)	12% or (2)	19% or (3)

Conclusion: A majority believes that Smart Corridor operations are satisfactory, but there is room for improvement

N/A: 25% or (4)

3. Have your expectations been met?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
6% or (1)	19% or (3)	44% or (7)	19% or (3)

Conclusion: A majority believes that their operational expectations have not been met

N/A: 12% or (2)

4. Were you satisfied with the development of the maintenance process?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
0%	31% or (5)	25% or (4)	6% or (1)

Conclusion: The maintenance process has room for improvement

N/A: 38% or (6)

5. Has maintenance of Smart Corridor elements proven to be satisfactory?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
6% or (1)	25% or (4)	25% or (4)	6% or (1)

Conclusion: Opinions on the satisfactory performance of maintenance efforts is broadly distributed

N/A: 38% or (6)

6. Have your expectations been met?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
0%	25% or (4)	38% or (6)	25% or (4)

Conclusion: A majority believes that their maintenance expectations have not been met

N/A: 12% or (2)

7. Was planning for Smart Corridor operations and management adequately handled?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
6% or (1)	50% or (8)	25% or (4)	13% or (2)

Conclusion: A majority believes that O&M planning was adequately handled

N/A: 6% or (1)

8. Are there any institutional barriers in existence that have impacted Smart Corridor's operations and management activities?

Absolutely YES	To Some Extent YES	To Some Extent NO	Absolutely NOT
19% or (3)	62% or (10)	19% or (3)	0%

Conclusion: A strong majority believes that institutional barriers existed that impacted SC O&M

N/A: 0%

6. LESSONS LEARNED: INSTITUTIONAL CONSIDERATIONS

6.1 INTRODUCTION

In this section, some insights into what could make a Smart Corridor experience "better" are described. A series of recommendations have been derived by the Project Team (with concurrence from the SCTC) based upon the extensive comments received during the SC Agency and Consultant interviews and workshops. These represent the key findings as a whole and are not meant to replace or supercede the many individual recommendations made by the interview and workshop participants (as found in Appendices A-F).

The organization of these recommendations is structured along the lines of the FHWA's PCB program's "ITS Integration Course" training modules (as described in Section 1.3). This approach was chosen in order to help other Agencies to identify recommendations relevant to a specific project phase, and is particularly well-suited to multi-Agency projects.

6.2 SHORT- AND LONG-TERM PLANNING NEEDS

1. Develop an agreed-upon understanding of the project's long-term vision within/between all participating stakeholders.
    - Establish a clear strategy for achieving this vision
    - Document the strategy
    - Communicate the strategy clearly and frequently to all stakeholders
2. Ensure dedicated support/commitment from all levels of management.
    - Identify how to get "buy-in" at different Agency levels
3. Identify needed changes in Agency policy to support project.
4. Identify goals that are not just operational in nature (e.g., establish a training/experience goal so that the project can retain value beyond its functionality, etc.)
5. Resources (e.g., time, money, facilities, etc.) should be provided for continuous training of Agency staff.
6. Establish a "Lead Agency" based upon which Agency has (or can obtain) the necessary funding and/or has the desire and resources to accomplish the objectives.
7. Plan for O&M at an early stage in the project planning.
    - Ensure that O&M expectations/considerations are defined in the requirements stage
    - Establish/maintain on-going O&M budget
    - Ensure that each stakeholders pays his "fair share" of the O&M budget
    - Clearly establish, define, and document agreed-upon O&M responsibilities within/between all stakeholders

- Resolve any potential policy differences
- Determine staffing and operational needs (e.g., 24-hours-a-day/7-days-a-week operations, etc.)

8. Flexibility to technological changes should be built into the plan.
9. Plan to execute the project or program in shorter, multiple phases rather than larger, more complex projects.
10. Perform an-in-depth risk analysis before committing resources in order to plan and budget better.
11. Define the Evaluation up-front to enable "before" data to be captured as a baseline for comparison to "after" data.
12. Maintain project enthusiasm.
13. Maintain firm project scheduling in all phases of the project.
14. Carefully examine long-term goals of the Agency and its ability to support such a program over time.
15. Review other, similar programs and "learn" early.

6.3 STAKEHOLDERS AND OPERATIONAL OBJECTIVES

1. Establish and maintain inter-Agency coordination and cooperation throughout the project.
    - Develop mutual trust and respect within/between stakeholders by working together; not at cross-purposes
    - Merge previously uncoordinated agendas to traffic management into a cohesive strategy by recognizing that the transportation system is a shared resource and that one stakeholder's actions may have an impact on other stakeholders
    - As necessary, develop written agreements, memorandums-of-understanding (MOUs), charters, etc. between all stakeholders
2. Decide "who's-in-charge" of each phase/component of the project up-front and in concurrence with all stakeholders (e.g., one particular stakeholder, a team of stakeholders, shared responsibility between all stakeholders, etc.).
    - No one Agency involved in a multi-jurisdictional ITS project should carry the sole responsibility for day-to-day operations
    - Responsibility should be distributed to promote inter-Agency coordination and cooperation so that operations remain a collaborative venture
3. Establish dedicated team(s) and individual project champions to develop, deploy, operate, and maintain the project/system.
4. To the greatest extent possible, ensure continuity of staff in order to let relationships develop/grow and essential project knowledge to remain "in-house".

- Carefully select team members with adequate knowledge and experience to complete task

5. Determine if the project's end-product will be a demonstration system (i.e., implemented just to demonstrate if a particular technology/concept works) or an operational system (i.e., implemented in order to operate effectively over a long, continuos period of time) and clearly identify performance requirements.
6. Ensure that all project meetings (e.g., Steering Committees, Technical Sub-Committees, etc.) meet regularly, operate as an open forum, and are productive.

Develop Agendas

- Identify and address issues and problems
- Build clear consensus on a resolution/mitigation measure

Keep Minutes

- Effectively document issues, resolution strategy, and result
- Minimize the amount of time spent "re-visiting" the same issues

Follow-Up

- Develop a rolling "Action Item" tracking process
- Identify issues at-hand
- Identify responsible parties
- Target resolution dates
- Develop methods to ensure actions got completed

7. ITS projects aimed at improving traffic management should collect sufficient data before project implementation to allow quantitative measures-of-effectiveness (MOEs) of the system.
8. A viable system Evaluation plan should be developed during the design and development of the project.
9. Clearly establish the motoring public's role in the project.
10. Keep Agency roles generally consistent with their own mission.
11. Ensure that the project's "Operational Objectives" or "Concept-of-Operations" are articulated/documented clearly, understood in the same manner by all involved stakeholders, and adopted into each stakeholder's "mission".

6.4 INFORMATION NEEDS AND SHARING

1. Determine what data/information is necessary to each Agency in order to fulfill its "mission".

- List "current" level of information sharing
- List "desired" level of information sharing

- Assess your ability to provide this data/information "in-house"
- Identify data/information "gaps"
- Identify other stakeholders capable of providing needed data/information

2. Determine what Agency operations are needed in order to fulfill its "mission".
   - List "current" level of operations
   - List "desired" level of operations
   - Assess your ability to provide these operations "in-house"
   - Identify operational "gaps"
   - Identify other stakeholders capable of providing these operations
3. Establish/maintain an effective information sharing process and/or mechanism within/between all stakeholders.
4. Clearly identify what information is to be shared.
   - Type (e.g., video, vol/occ/speed data, etc.)
   - Format (e.g., serial, NTCIP, etc.)
   - Frequency (e.g., once-per-second, every 5-mins., etc.)
5. Identify and respect data/information "ownership". However, do not let this become an obstacle to sharing.
6. Involve operators in decision-making process.
7. Within an organization, ensure information channels: both peer-to-peer and through to senior management.

6.5 OPERATIONAL IMPLICATIONS OF INFORMATION SHARING

1. Investigate the identified information sharing "gaps" (from Section 6.4).
   - These indicate where information sharing arrangements need to be re-addressed
   - Determine the impact that shared data/information may have on your Agency's operations
2. Investigate the identified Agency operational "gaps" (from Section 6.4).
   - These indicate where Agency operations need to re-addressed
   - Determine the impact that shared operations may have on your Agency's data/information sources
3. Clearly partition the areas of operational responsibility within/between all stakeholders.
4. Establish/define stakeholder agreements/MOUs/commitments to all identified operational and maintenance roles/responsibilities.
5. Build/maintain stakeholder consensus throughout the project.

6. Consider the use of a "non-operational" Agency as the project lead in order to build bipartisan, unbiased consensus within/between all stakeholders.

6.6 DESIGN AND IMPLEMENTATION CONSIDERATIONS

1. Incorporate a pre-planned, disciplined, end-to-end "Systems Engineering Process" throughout the project's life-cycle.
    - Agencies and Consultants alike should be trained to employ this process including configuration management, peer reviews, risk management, etc.
2. The reliability, functionality, and objectives of large-scale ITS projects should be clearly defined, and agreed-upon by all participating stakeholders.
3. Develop/define clear, concise, and agreed-upon system requirements.
    - Determine requirements at every level, (e.g., functional, performance, reliability, physical, environmental, etc.)
    - Ensure that requirement inputs/expectations are obtained from every stakeholder
    - Ensure that requirements are properly elicited, documented, baselined, and managed for change
    - Ensure that requirements are traceable, verifiable, and testable
4. Develop designs, specify equipment, and install system components based on the developed requirements.
5. Develop the Acceptance Test Plan (ATP) based upon the system requirements.
6. The Agency stakeholders should be involved in the definition, development, execution, and approval of the ATP.
7. The ATP should be comprehensive in nature (e.g., stand-alone subsystem testing, system boundaries definition, tests for sustained performance, integrated system test, use IEEE-style software verification and validation, etc.).
8. Develop a phased/incremental approach within the project's design, development, and implementation process, with frequent "builds" to establish progress.
    - Develop MOEs on which to base this approach (e.g., technical feasibility, cost-effectiveness, ease-of-implementation, etc.)
    - Choose a set of basic functions (that are identifiable and complete) to implement first, then bring additional elements onto that stable baseline
    - Establish testable milestones
    - Establish a formal risk identification and assessment strategy
9. Prototypes should be used for the introduction of new system components prior to finalizing design in order to ensure usability and compatibility with other system components
10. ITS projects should have finite life-spans with flexibility in the design, development, and implementation stages to allow for changes in technology.

11. Ensure that the design and development processes are "visible" to all parties (Agencies and Consultant).
    - Allow adequate opportunities/time for stakeholder reviews
    - Schedule regular review meetings
    - Ensure that the reviews are accomplished by staff with the appropriate skills
    - If such technical oversight capabilities are not resident in-house, contract out to a 3rd party
12. Involve operators in decision-making process.
13. Agencies should require frequent/periodic progress reports form the Consultant during all phases of the project in order to ensure that the project remains on schedule and does not deviate from the SOW.
14. Avoid the use of proprietary equipment/interfaces (where possible).
15. Ensure that the implementation of the communications network is a top-priority.
    - Design should be based on data/information support needs
    - Installation should occur before other components
16. Evaluate commercial-off-the-shelf (COTS) products for integrity and suitability before committing to their use.
17. Perform an extensive design approach to ensure that more in-depth, comprehensive design alternatives result.
18. Design and develop the system using an "open" systems architecture in order to promote modularity, flexibility, extendibility, scalability, and the ability to be modified easily.
19. Involve all levels of design and development staff and conduct peer reviews.
20. Carefully weigh all requirements against available technology; thereby ensuring that the ensuing design is realistic, cost-effective, and capable of being supported.
21. To the extent possible, station the system developers at the operations site in order to record "problems" and minimize confusion.

6.7 PROCUREMENT STRATEGIES AND CONTRACTING OPTIONS

1. State clear, concise Terms and Conditions that effectively manage contract risk.
2. Establish realistic project costs and secure funding up-front.
3. Consider a "best value" approach rather than "low bid".
4. Establish a technical oversight team to define a realistic project scope.
5. Plan for an integration phase.
6. Consider a beginning phase contract to scope out the effort, document requirements, and sort out institutional policy differences, then follow up with a second phase to implement the effort.

7. Enact appropriate contracting methods suitable to the task at-hand [e.g. do not use a Firm Fixed Price (FFP) contract for undefined software development, etc.].
8. Cost Plus Fixed Fee (CPFF) or Time and Materials (T&M) contracts should be considered for any scoping phases, because neither the Agencies nor the Consultant can know ahead of time how to estimate for the unknowns of requirements definition and institutional factors.
9. Procurements should be streamlined (to the greatest extent possible).
10. For a program with multiple projects/contracts, distribute contract responsibilities (as far as possible) to ensure that every Agency has a "stake" in the final outcome.
11. Consider a FFP contract with a very well-defined scope and all equipment procured by the Consultant.
12. Consider the implementation of a "turn-key" system.
13. Ensure the contract specifies in-depth, comprehensive documentation and training.

6.8 OPERATIONS AND MANAGEMENT

1. Plan for O&M at an early stage in the project planning (see Section 6.2).
2. Do not fully automate operations in the initial stages of the project → allow for operator input/intervention.
3. Ensure appropriate staff is available/trained to "de-bug" and "troubleshoot" software and hardware problems.
4. Ensure support/commitment by senior management.
5. Determine staffing and operational needs (e.g., 24-hours-a-day/7-days-a-week operations, etc.) at an early stage in the project planning.
6. Ensure that the resultant system is used on a daily/continuous basis. Do not implement a project that remains idle.
7. Tailor the project's/system's operations to the City's need and Agencies' capabilities.
8. Ensure system stability before beginning continuous operations.

7. LESSONS LEARNED: TECHNICAL CONSIDERATIONS

7.1 INTRODUCTION

In this section, the workshop findings that involve the Smart Corridor's technical issues are presented. The Project Team has derived a series of recommendations (with concurrence from the SCTC) based upon the extensive comments received during the SC Agency workshops. These represent the key findings as a whole and are not meant to replace or supercede the many individual recommendations made by the workshop participants (as found in Appendices A-F).

The organization of these recommendations is structured along the lines of the system components implemented within Smart Corridor. This approach was chosen in order to help other Agencies to identify recommendations relevant to a specific technology, and is particularly well-suited to programs that contain multiple projects/functionality.

7.2 SMART CORRIDOR SYSTEM COMPONENTS

Technical considerations within the Smart Corridor project were discussed at all of the Agency Workshops conducted for this project. This was the only opportunity to gather data/information on the SC's chosen systems and technologies, as there was not enough time available within the "one-on-one" interviews to cover this topic. SC technical considerations covered the following aspects:

1. Technical Elements
    - Incident Detection/Data Collection
    - Closed Circuit Television (CCTV)
2. Advanced Transportation Management Systems (ATMS)
    - Ramp/Connector Metering
    - Traffic Control Systems
3. Incident Management
    - Decision Support System (DSS)
4. Advanced Traveler Information Systems (ATIS)
    - Highway Advisory Radio/Highway Advisory Telephone (HAR/HAT)
    - Changeable Message Signs (CMS)
    - On-Line Access (i.e., Internet)
5. Systems Integration
    - Graphical User Interface (GUI)
    - Data Base Systems
    - Software/Operating Systems
    - Hardware Components

- Communications Network
- Integration Process

6. Acceptance Mechanisms
    - Test Procedures
    - Documentation

Overall, workshop participants generally believe that the key issues considered in reaching technical decisions within Smart Corridor centered around the following themes:

- Operability
- Maintenance
- Cost
- Year 2000 Compliance

Thus, each technical decision made was based upon consideration as to whether the element would fulfill operational requirements, in a maintainable fashion, with relative cost effectiveness. Oftentimes the Agencies were able to capitalize upon existing technical capabilities to enhance SC's technical effectiveness.

The sections that follow summarize the workshop participants' expressed viewpoints regarding Smart Corridor's technical lessons learned.

7.3 TECHNICAL ELEMENTS

7.3.1 Incident Detection/Data Collection

1. Capitalize on existing incident detection/data collection technical capabilities.
2. Obtain adequate funding for improvements early-on.
3. Specify coverage area and type of improvements (e.g., additional instrumentation, O&M concerns, etc.).
4. Establish second-source confirmation of incidents (e.g., via CCTV, police, cellular call-ins, etc.).
5. Distinguish between the information sources (above) and assign an "importance value".

7.3.2 Closed Circuit Television (CCTV)

1. Develop standardized requirements such as camera placement, height, control, etc. but not on the actual cameras used (i.e., the vendors providing the physical cameras).
2. Allow the use of different vendors to provide cameras (i.e., as long as the vendor can meet the requirements specification, the physical camera used does not matter).

3. Introduce compatibility between CCTV systems in different Agencies through the development of a "standard control approach" for both data (control) and video image viewing. In a CCTV system, two different control signals need to be considered.
   - From the manual control unit to the central control unit
   - From the central control unit to the camera in the field.

   Explanatory Note: *In the Smart Corridor systems, it was recognized that the important link for ensuring compatibility between Agency systems is in the manual control to central control unit link. As long as an operator could address the central control unit, then the camera could be controlled and the image viewed. This is reflected in Exhibit 7.1.*

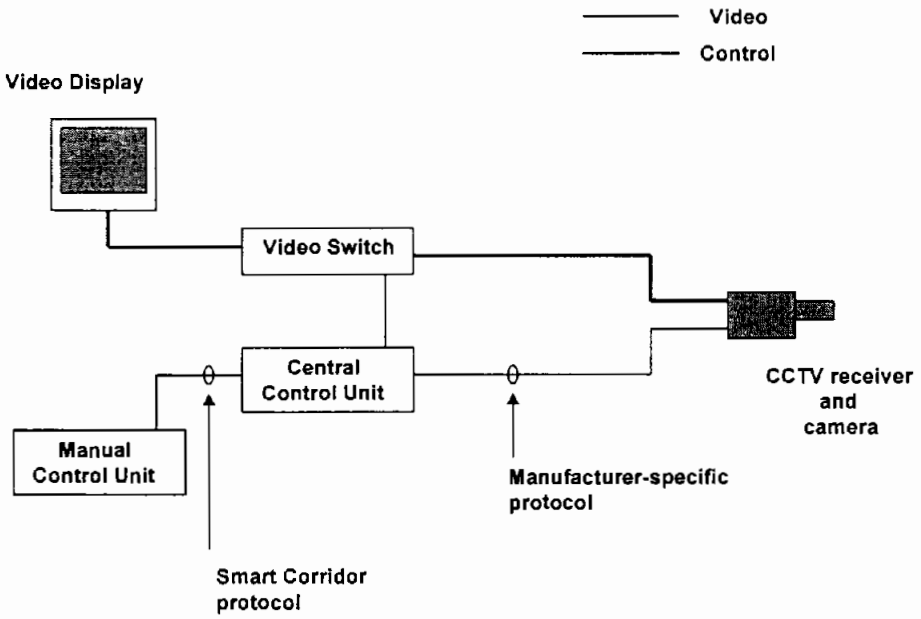

Exhibit 7.1 - Typical CCTV System

The SC system CCTV design developed a non-proprietary, Agency-owned communications protocol from the manual control unit (in SC's case a workstation) to the central control unit. This protocol was used by LADOT and the City of Santa Monica in the procurement of their CCTV systems and has guaranteed that these two Agencies can share CCTV control without the need to develop new software. Caltrans' CCTV system was designed for its overall District 7 freeway ATMS operations. Their CCTV system specification was of an "open standard" for all PS & E construction contractors; however, it was not designed specifically for the Smart Corridor CCTV system. Therefore, the SCEMIS contract has provided additional workstation software so that the Caltrans SC cameras can be controlled from a SC workstation.

4. Coordinate video insertion, integration, and control in advance with the vendor.
5. Develop X/Y coordinates within CCTV frame/image to help establish dynamic presets. This functionality can be used to confirm incident information (e.g., location, type, severity, etc.).

7.4 ADVANCE TRANSPORTATION MANAGEMENT SYSTEMS (ATMS)

7.4.1 Ramp/Connector Metering

1. Ramp Metering
    - Take many factors into account (e.g., freeway & ramp volume/occupancy, in-effect plan, time-of-day, etc.) when developing your ramp metering philosophy
    - Ensure adequate storage space on the ramps
    - Ensure coordination with the arterial traffic control system in order to minimize queues "spilling-over"
2. Connector Metering
    - Develop a comprehensive marketing/public relations campaign to engage community support
    - Ensure adequate storage space along the freeway connector ramps to minimize traffic queuing on the connector ramps
    - Train/educate staff on connector metering strategies

7.4.2 Traffic Control System (TCS)

1. Coordination between Agency traffic control systems (e.g., signal timing plans, etc.) alleviated arterial traffic congestion due to incidents.
2. Obtain funding early-on.

7.5 INCIDENT MANAGEMENT

7.5.1 Decision Support System (DSS)

1. Use of an automated incident response planning process to assist operators in their decision-making process is a capable and worthwhile pursuit.
    - Ensure desired functions are implemented
    - Determine the appropriate level of assistance provided to the operator
2. Develop the DSS through a team effort involving all stakeholders.
    - Agencies present high-level requirements to Consultant
    - Ensure that the actual operators have the opportunity to provide input into the DSS design
    - Consultant then works closely with the Agencies to develop a detailed specification
    - Developed options are then presented to the Agencies
    - The Agencies review the options, examine the pros and cons of the options, and influence the design (as necessary)

- Factor continued DSS support (in terms of operations and maintenance) into the process of determining the requirements and design for the DSS

7.6 ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS)

7.6.1 Highway Advisory Radio/Highway Advisory Telephone (HAR/HAT)

1. Evaluate the "value" of using such technology.
    - Determine where such concept can be useful (e.g., event generation areas like a stadium)
    - Investigate technology capabilities/"soundness" (e.g., directional messaging capabilities, broadcast power, etc.)
    - Determine data/information delivery "timeliness"
    - Investigate frequency allocation, licensing, and interference
    - Investigate maintenance costs

7.6.2 Changeable Message Signs (CMS)

1. Undertake comprehensive human factors studies (e.g., height, placement, angle, lettering, colors, and message content) prior to implementation.
2. Select CMS that allow a variety of messages to be displayed as a way of conveying information to motorists.
3. Establish policies (e.g., message generation, display/signing strategies, coordination with other Agencies, etc.) prior to implementation.
4. Investigate aesthetic considerations (e.g., visual aspect on roadways may be negative for an Agency because the signs are too large, use is ineffective, etc.).
5. Ensure that multiple-Agency CMSs can be integrated/interfaced into a seamless system.
6. Consider the use of dynamic trailblazer signs along arterial streets to display alternate routes to the freeway in response to incidents.
    - Develop detailed requirements and cost estimates
    - Discussions have revealed that trailblazer signs are most effective over the roadway; not on the roadside
    - Investigate the use of combining static data with dynamic information, and placing trailblazers at event-generation areas in addition to diversion routes

7.6.3 On-Line Access

1. Consider up-to-date technologies.
2. Investigate the use of an external Internet interface that will enable community access to congestion and incident information via the World Wide Web.
    - Develop a standard interface for your system for Internet access

- Ensure a dedicated connection to an external web-server
- Ensure that implementation is with "state-of-the-art" Internet technology

7.6.4 Media Involvement

1. Determine appropriate levels of involvement with the media.
2. Define data/information requirements.
3. Consider public-private partnerships to forward goals.

7.7 SYSTEMS INTEGRATION

7.7.1 Graphical User Interface (GUI)

1. Develop clear, concise, and agreed-upon requirements.
2. Undertake development effort at the appropriate time.
   - After Agency operational strategies are finalized
   - After system functionality is defined/agreed-upon (so that the Agencies understand what functions the GUI needs to perform/support)
3. Model GUI movements between screens. This is a critical aspect of the GUI design for incident management.
4. Undertake an interactive GUI development process between the Agencies and Consultant in order for an acceptable product to result.
   - Clearly define functional requirements
   - Use an open process that involves Agency users
   - Show intermediate deliverables
   - Use Agency operators to provide clarifications on requirements
   - Use prototyping extensively in the design stage in order to gain Agency interaction/feedback, review, and approval
5. Investigate on-going maintenance considerations and allocate sufficient resources to Consultant to further enhance/modify the GUI based upon input by actual Agency operators using the system

7.7.2 Data Base Systems

1. Perform a preliminary design and utility and trade-off analyses for selection of databases, operating systems, expert system, and hardware environments for the system servers and the operator workstations.
2. Thoroughly evaluate the state-of-the-practice technology. Consider factors such as:
   - Interoperability, performance, simplicity to configure, user-friendliness, ease of update, etc.
3. Ensure that the selected database tool can support a mechanism to capture "before" data for an evaluation.

7.7.3 Software

1. In selecting software, consider the following:
    - Consider and plan for maintenance costs (including personnel)
    - Plan ahead for expenditures and engineering efforts associated with continuously-available software upgrades, in order to keep up with moving technology
    - Clearly specify requirements (for example) in areas such as:
        - Multi-tasking needs, modularity, ease-of-modification
        - GUI support
    - Have the Consultant provide recommendations (along with pros and cons)
    - Have the Agencies review the recommendations to the best of their ability
    - Selection based upon the best technology available at the time and its adherence to the known specifications
2. Provide the end-user with all source code for project-developed software

7.7.4 Hardware

1. In selecting hardware components, consider the recommendations of Section 7.7.3 above.
2. In addition, incorporate the following items into your selection process (as appropriate):
    - Postpone hardware procurement as long as practical
    - Once hardware is installed, upgrades should be planned for
    - Plan for the risks associated with vendors going out of business
    - Establish mitigation techniques
    - Plan ahead for maintenance issues, including establishing maintenance contracts, and planning for associated costs (including personnel resources)
    - Plan for hardware enhancements to keep up with technology
    - Establish an architecture that supports modularity (in order to contribute to a more adaptable system)
    - Where possible, implement the system with less specialized, more standardized, COTS hardware
    - Maintain a stock of spare parts
    - Define roles and responsibilities

7.7.5 Communications Network

1. Establish the communications networks as a top priority.
2. Consider the use of Ethernet-based communications network that takes the form of LANs within the Agency control centers, and connects these LANs using links to other control centers
3. Consider the following factors within the communications network design.
    - Status of the existing field infrastructure; Agency wants/needs to keep or upgrade their existing infrastructure
    - Experience gained from previous, successful communications networks
    - Use of existing communications infrastructure
4. In addition, incorporate the following items into your selection process (as appropriate):
    - Associated implementation costs should be identified at the outset of a project
    - Pre-planned maintenance for the system is critical; maintenance needs should be considered as a high priority and included in the budget
    - Roles and responsibilities should be clearly defined
    - A "shared" system requires special attention to definition and design so that sharing is facilitated
    - Long-term needs and risks should be considered for issues such as reliability, bandwidth, and even for determination of how deep to bury the fiber

7.7.6 Integration

1. Use an iterative process in the development of the software and the integration of the system.
2. Establish appropriate integration "sequencing".
    - Finalize Agency operational procedure before any GUI development
    - Do not try to integrate too many complex components at one time
    - Incorporate a modular/phased integration approach by thoroughly integrating and testing a selected subset of components before adding others into the system under test (i.e., frequent "builds").
3. Ensure that vendors are supplying systems/products that support an "open" systems architecture.

7.8 ACCEPTANCE MECHANISMS

7.8.1 Acceptance Test Procedures

1. Define, develop, and conduct the Acceptance Tests jointly between Agency and Consultant staff.
    - Ensure that the Acceptance Tests are based upon the defined and agreed-upon requirements (e.g., reliability, performance, operational and maintainability responsibilities, etc.)
    - Ensure that the tests are comprehensive, thorough, and incorporate stand-alone testing (e.g., functionality, component, subsystem, etc.)
    - Ensure full-system capability testing (including tests for sustained performance and system "boundaries")
    - Establish clear, concise, and agreed-upon system acceptance criteria
    - Establish a schedule for Acceptance Testing within the overall project scope
    - Perform Acceptance Testing according to documented test procedures
    - Document every step of the Acceptance Testing in order to positively impact system design, operations, and maintenance efforts
2. If the Agencies lack the appropriate skills "in-house" to properly review the Acceptance Tests, seek 3rd party support.
3. Minimize "debugging" during the Acceptance Testing process.
    - Debugging can cause potential problems because changing software to affect one function can easily affect other functions which may have previously been demonstrated/accepted, and perhaps then should be re-tested (i.e., carry out regression testing)
4. Consider a reasonable "burn-in" period as part of the Acceptance Testing (i.e., the system needs to perform acceptably during a 30-day period of operational use prior to acceptance of the system).

7.8.2 Documentation

1. Provide detailed documentation on the system.
    - Operational Use (i.e., how to use the system)
    - Detailed Requirements (i.e., what the system does)
    - System Design (i.e., how the system was structured to meet the requirements)
    - Implementation (i.e., how the software performs its functions, how the system facilitates maintenance)
2. Develop detailed documentation requirements early on in the program.

8. LESSONS LEARNED: STAKEHOLDER USES

8.1 INTRODUCTION

This section presents a number of actions that the Smart Corridor stakeholders are already putting into practice in their current day-to-day activities as a result of their own experiences in participating in the Smart Corridor Project.

8.2 CALTRANS

1. Use of a shared central system with access by other Agencies.
    - Central data repository/database
    - CCTV/video system
    - Common communications standards
    - Information sharing
    - Computerized control of ITS field elements
    - Provision of information/data to value-added re-sellers and the motoring public
2. Use of a centralized expert system within an overall transportation management system.
3. Use of GUIs to operate/interface to the expert system.
4. Real-time traffic information dissemination through the use HAT systems. Currently being modeled for:
    - TravelTip (Orange County)
    - TravInfo (San Francisco Bay Area)
5. Use of system technologies that had existed outside of Smart Corridor but had not been uniformly implemented were given a thorough demonstration and proven in Smart Corridor:
    - Color CCTV cameras
    - Enhanced ramp metering
    - Ramp termini queue loops
    - Signal interconnection
    - Surface street CMS
    - Extended Freeway Service Patrol (FSP) hours-of-operation

8.3 LADOT

1. Use of an arterial incident detection algorithm within the Adaptive Traffic Control System (ATCS) portion of ATSAC.

8.4 CULVER CITY

1. Integration of the "learned" technology towards signalization, interconnectivity, and community-access television (CATV).
2. Maintain the legacy of inter-Agency cooperation on regional transportation issues.

8.5 CHP

1. Use of the FSP program (in its current state-of-operations).
    - Use of private tow companies/drivers/equipment instead of State-owned resources
    - Having the private tow companies under contract to the State for specific sections of roadway
2. Participation in the Southern California Priority Corridor SHOWCASE due to the institutional cooperation started within Smart Corridor.

8.6 TRANSCORE

1. Use of a formal "Systems Engineering Process" within all design, development, and implementation efforts.
2. Introduction of contract language to mitigate risk.
    - Just compensation for delays caused by prolonged Agency review periods
    - Clear, concise documentation establishing Agency and Consultant roles and responsibilities
3. Incentive/reward program for staff in order to maintain project commitment and enthusiasm when schedule delays/slippage occur.
4. Emphasis on "Design-to-Budget" approaches for undefined SOWs, especially software development.
5. Use of rolling "Action Item" lists at company and project meetings.
    - Clearly define issues
    - Clearly assign responsible party
    - Target resolution date
6. Structure design and development activities with the Client in mind.
    - Schedule the necessary "face-to-face" meetings
        - Requirements elicitation
        - Design reviews
        - Prototype reviews
        - GUI screen reviews
        - Establish frequent/consistent meeting schedule
    - Maintain close communications (e.g., daily phone calls, e-mails, faxes, etc.)