ORANGE COUNTY INTELLIGENT VEHICLE / HIGHWAY SYSTEMS STUDY DRAFT

FINAL REPORT

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jhk & associates

ORANGE COUNTY INTELLIGENT
VEHICLE / HIGHWAY SYSTEMS STUDY

DRAFT
FINAL REPORT

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Introduction

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1. INTRODUCTION

This document represents the Final Report for the Orange County Intelligent Vehicle-Highway Systems (IVHS) Study, prepared for the Orange County Transportation Authority (OCTA). The purpose of this report is to document the findings of the IVHS Study and present the proposed system programs and elements. The study will also evaluate the proposed programs and elements in order to assess benefits to the Orange County transportation system.

The JHK & Associates Project Team conducted this study under the supervision of an IVHS Interagency Advisory Committee (IAC), as well as the OCTA's Technical Advisory Committee (TAC) and Signal Roundtable. The IAC consisted of representatives from four cities (Anaheim, Irvine, Santa Ana and Garden Grove), OCTA, Caltrans, FHWA and the University of California-Irvine. The TAC and Signal Roundtable represent, respectively, policy and technical representatives from all local and regional transportation agencies and governments within the County.

1.1 OVERVIEW OF THE STUDY

Intelligent Vehicle-Highway Systems (IVHS) are defined as "the application of advanced technology to improve the operation of our highway and public transportation systems" (per IVHS America's Strategic Plan for Intelligent Vehicle-Highway System in the United States, May 1992). The goal of this study was to provide a 20-year Master Plan for implementation of IVHS throughout Orange County, which would provide an opportunity for coordination between local and regional agencies in implementing and operating IVHS elements. Specific objectives as defined by OCTA were to "identify and recommend IVHS, signal coordination, signal pre-emption, arterial/freeway traffic surveillance and control, and traveler information systems activities for Orange County"; and also to "develop a network of streets and roads appropriate for implementation of those activities". The Study then investigated the institutional and technical requirements of implementing the system, and assessed programs, costs and available funding.

To carry out the Study, the Project Team first investigated the full spectrum of IVHS technologies and the current and future "state-of-the-art" technologies, along with current programs in the County which are applicable to IVHS. Current programs such as the Caltrans Traffic Operation System Master Plan and various traffic management system programs in Cities such as Anaheim, Irvine and Santa AM will provide key elements of the infrastructure which the County-wide IVHS network can build on and enhance, as well as expand throughout the County where required.

As a preliminary assessment of system needs and the required scope of improvement, traffic conditions were reviewed on a County-wide basis, then modified to represent various types of roadways in the IVHS network. The nature of this network is that it is inclusive of all freeways, major and minor arterials, and local collector streets, as well as related public transportation facilities. As Caltrans and OCTA have previously focussed extensively on a Countywide freeway operations capability (most recently through the Caltrans Traffic Operations System [TOS] Master Plan), much of the focus in this study is on the surface street and transit elements.

Interviews were conducted with all pertinent local, regional and neighboring agencies as well as a number of private trip-generators. This was done to ascertain the institutional issues. Additional input in this regard came from the IAC, TAC and Signal Roundtable members. This was instrumental in formalizing the proposed IVHS architecture and Master Plan.

1.2 REVIEW OF IVHS AREAS OF APPLICATION

Below is a summary of the five areas of IVHS implementation that were addressed in this study:

- Advanced Traffic Management Systems (ATMS)
- Advanced Traveler Information Systems (ATIS)
- Advanced Vehicle Control Systems (AVCS)
- Commercial Vehicle Operations (CVO)
- Advanced Public Transportation Systems (APTS)

1.2.1 - Advanced Traffic Management Systems (ATMS)

ATMS functionally builds upon the work which has been done in the following areas:

- Surface Street Traffic Signal Control
- Freeway Traffic Management

The purpose of ATMS is to improve mobility through the real-time management of traffic in response torecurrent and non-recurrent congestion and in conjunction with incident and event management strategies.ATMS functions on two operational levels, local (one agency) and corridor (multiple agency). Local-level improvements may focus on a specific area in a city where congestion is concentrated, or may be city-wide in nature. However, as commuter traffic in the County generally crosses jurisdictions and utilizes both surface street and freeway components, corridor traffic management plays an increasingly important role. Importantly, corridor traffic management considers the freeway and major surface streets as equally important components in the corridor, and as a result, the development of traffic management strategies and responses must involve all jurisdictions within that corridor. The development of "Smart Corridor" techniques as recommended in a Statewide Study performed by Caltrans in 1990, identifies roadways and ATMS components within specific corridors, six of which have been identified in Orange County.

The characteristics of ATMS are as follows:

- Use of real-time traffic flow information to define operational strategies and to detect or confirm incidents.
- Development of open interface between different agencies, allowing the sharing of traffic data for joint analysis and development of strategies, typically using decision support mechanisms such as expert systems.
- Providing upgraded traffic responsive control including signal timings, ramp meter rates, and routing strategies using changeable message signs, to enhance traffic flow in the corridor.

Elements typically associated with ATMS are as follows:

- Traffic Management Centers (TMC) for surface street operations
- Traffic Operations Centers (TOC) for freeway operations

- Surveillance and detection equipment to provide real-time traffic flow data and incident detection
- Changeable Message Signs (CMS) for en-route advisory and routing information
- Real-time responsive traffic signal control system, including priority control as necessary for emergency vehicles or for optimized transit vehicle movements
- Incident management strategies utilizing coordinated real-time information and dispatching strategies

ATMS is implemented almost entirely within the public sector or within quasi-public activities (i.e., privately-financed construction of toll roads). Thus, much of what is recommended within this IVHS Study will involve these types of elements.

1.2.2 - Advanced Traveler Information Systems (ATIS)

ATIS builds upon the current methods of traffic information gathering and dissemination, so as to provide timely, accurate information on demand, both in terms of specific routes and in terms of different transportation modes. The nature of ATIS is that both pre-trip and en-route information are critical to the traveler. With ATIS elements in place, the traveler can select or be advised of an alternate route which is the least congested, or alternatively select a mode which reduces a traveler's dependence on single-occupancy vehicles (SOVs). The potential result of providing the above information is reduction of roadway travel delay and also, through providing information on mode alternatives, a reduction in vehicle-trips. As with ATMS elements, ATIS elements would comprise a major near-term component of the IVHS network.

Physical implementation of ATIS can be separated into public sector elements and private sector elements. The public sector would provide the capability of roadway-based information gathering through ATMS, then coordinating the data into a central clearinghouse (e.g., a traveler information database), where it can then be disseminated in textual or graphical form to a variety of agency, media and public users. The public sector would also provide the capability of transmitting this information to vehicles traveling along its facilities. Public sector elements may include:

- Dial-Up Services (e.g., Highway Advisory Telephone)
- Media Interface (Two-way)
- Bulletin Boards on PC's (interactive)
- Interactive terminals in public locations
- Graphical dissemination through local cable TV franchises

In turn, the private sector can provide different means of disseminating data. These can be separated into service-based and technology-based elements. These include:

Service-Based

- Private information services (dial-up)
- Dedicated traveler information services (e.g., hand-held units, radio data services, silent radio)
- Trip-planning service (interactive)

Vehicle-Based

- In-Vehicle Navigation and Route Guidance Systems
- Digital traffic information receivers (i.e., radio data systems)
- In-vehicle mapping and signing displays
- In-vehicle advisory systems for weather, roadway hazards

A key role of public sector ATIS elements is to provide the information and standard interface capabilities which can support private sector ATIS initiatives.

1.2.3 - Advanced Vehicle Control Systems (AVCS)

AVCS is intended to enhance mobility through first, improving traveler safety by averting incidents, and secondly, improving capacity and traffic flow. Currently, infrastructure-based AVCS elements (i.e., located in highways) are undergoing research. These elements, from a public-sector standpoint, include providing dedicated lanes for automatic vehicle platooning, as well as providing a continuous vehicle-roadway-central communications and tracking capability. Although AVCS is considered a longer term component of IVHS, the information gathering, exchange and dissemination capabilities in conjunction with vehicle-based elements are an outgrowth and extension of the capabilities required for ATMS and ATIS elements.

Much of the AVCS functionality, however, stems from autonomous (vehicle-based) improvements developed and marketed by the automobile, electronics and communications industries. These include the following:

- Anti-lock braking systems (now standard on many new vehicles)
- Automated braking and steering systems (for collision avoidance)
- Automated cruise control strategies, including vehicle speeds set based on locale and conditions, as well as adaptive strategies designed to maintain headways behind vehicles ahead)
- Automated vehicle guidance systems

AVCS in many ways is the ultimate technological development of IVHS, in which real-time information is shared between the vehicle and the roadway in a way which benefits both safety and mobility.

1.2.4 - Commercial Vehicle Operations (CVO)

CVO technologies provide for the expediting of commercial vehicle movements so as to reduce delays and enhance the movement of people and goods. These elements include the automation of a number of administrative and operational activities involving commercial vehicles, including trucks, intercity buses, and other commercial fleets. Providing travel information to support this improved movement of people and goods is also an important element. The issues typically involved in this area include interstate travel and regulation, and thus may be beyond the purview of the agencies in Orange County. However, CVO technologies can be utilized in conjunction with other IVHS components in order to provide improved information and to allow tracking of vehicle locations and data. Technologies included in CVO include:

- Automatic Vehicle Identification (AVI)
- Electronic Weigh-in-Motion (WIM) stations
- Two-way central-vehicle communications
- Automatic Vehicle Location (AVL) tracking
- Automated classification and permits processing through AVI and AVL technologies
- In-vehicle navigation and information for commercial vehicle operations

The nature of CVO to date is that such improvements have been recommended as a cooperative effort of the trucking industry and state agencies. Programs such as Help/Crescent in 6 Western States and Advantage I-75 in the Midwest and Southeast are examples of this cooperative public-private partnership.

1.2.5 - Advanced Public Transportation Systems (APTS)

The purpose of APTS elements is to provide improved information to the public on public transportation operations and availability, including real-time status. The potential impact of APTS is the increase of public transportation use and a reduction in overall vehicle-trips. This would lead to reduced congestion, pollution and fuel consumption. APTS technologies can be used both for public transportation vehicles and to promote the use of high-occupancy vehicle (HOV) facilities through ridesharing and other means.

Typical activities in the area of APTS are generally found within the public sector, and include the following:

- Static information concerning transit and other modes utilizing ATIS terminals and interface elements

- Real-time transit location information through vehicle tracking (via Advanced Vehicle Location [AVL] systems) and schedule maintenance

- Managing of fleet operations and maintenance of service based on real-time transit needs (i.e., additional buses during a period of unusually high transit use)

- On-board information for passengers

- Real-time displays at bus stops and transit terminals

- Automated fare collection using "Smart" card technology

APTS elements are likely to be developed in conjunction with ATIS, since much of the information to be disseminated from APTS will benefit the ATIS user.

1.3 INSTITUTIONAL ISSUES AND MASTER PLAN DEVELOPMENT

In addition to the development of proposed IVHS activities, the Project Team performed an exhaustive investigation of institutional issues on a local and regional basis, involving a series of interviews with all local, regional and neighboring agencies, as well as private sector trip generators and private traffic reporting entities. Based on these interviews, a series of operational constraints and interagency relationships were identified.

Among the issues which play a role in the development of IVHS activities are the following:

- Definition of both individual agency roles and interdependency of agency relationships in coordinated traffic management strategies.

- Definition of traveler information requirements for traffic and transit, and the dissemination requirements for pre-trip and during-trip travel information.

- Definition of information to be shared between agencies, and responsibilities for obtaining and distributing specific information elements.

As a result of the institutional issues raised, specific attention was paid to the constraints and requirements defined by the agencies. These in turn helped define the IVHS programs presented in the Master Plan. The Master Plan provided a specific focus on, in addition to the IVHS activities to be developed, the means of implementing these activities. This included development of a technical architecture incorporating existing local and regional elements, definition of a dissemination and information-exchange capability between agencies and users, and development of an agency framework for implementation of IVHS programs.

Specific roadways and areas for implementation were defined for the programs, along with appropriate funding sources. The IVHS Action Plan, which is presented under separate cover, presented under separate cover, presents a detailed, phased implementation plan for IVHS programs in Orange County.

1.4 ORGANIZATION OF THE REPORT

This Final Report is organized as follows:

1. **INTRODUCTION. These opening remarks.**
2. **CONCEPTUAL DEVELOPMENT OF IVHS**
   - Goals and Objectives
   - Strategies
   - User Services and Techniques
3. **ANALYSIS OF NETWORK**
   - Roadways
   - Public Transit Considerations
4. **INSTITUTIONAL ISSUES IN IVHS IMPLEMENTATION**
   - Local and Regional
   - Private Sector
5. **SYSTEM ARCHITECTUR E AND RECOMMENDED ELEMENTS**
   - Comparison of Different Structures
   - Recommended Elements
6. **THE STATE OF THE ART IN IVHS**
   - Functional Areas
   - Technologies
   - Applications
7. **SYSTEM CONFIGURATION FOR INFORMATION SHARING AND DISSEMINATION**
   - Interagency Link
   - Communication Requirements
8. **AGENCY CONSIDERATIONS**
   - Agency Structure
   - Supervision of Program Development
   - Staffing Requirements

9. **THE MASTER PLAN**
   - Description of Programs

10. **SYSTEM COSTS AND FUNDING**
    - Estimated Program Costs
    - Review of Potential Funding Sources and Opportunities

11. **BENEFITS ASSESSMENT**
    - Benefits of Element Groups
    - Estimate of Total System Benefits

The Final Report is accompanied by an Executive Summary, and as discussed above, an IVHS Action Plan.

2

Conceptual Development of IVHS

2. CONCEPTUAL DEVELOPMENT OF IVHS

2.1 INTRODUCTJON

This chapter presents the strategic approach and tool kit for development of IVHS activities in Orange County. This approach reflects the overall transportation needs of the County and considers to a great extent the existing interagency relationships and the ability of the current transportation management structure to support, operate, and maintain the various elements of IVHS.

The strategic approach involves a "top-down" strategy development process, which is then used as the basis for the IVHS element selection and program development process in the later chapters.

2.2 ORANGE COUNTY'S 2020 TRANSPORTATION VISION

Subsequent to much of the work done during this IVHS Study, OCTA has prepared a draft long-range strategic plan entitled the "2020 Orange County Transportation Vision." This document serves as a policy document for development of transportation improvements.

The 2020 Vision identifies three approaches for improvement of transportation facilities. These are:

- Freeway and Roadway Expansion
- Increased Transit
- Transportation Management

Additionally, the 2020 Vision identifies the need to "reduce traffic congestion, improve air quality and revitalize the economy" through the use of IVHS, and supports the use of IVHS and other newer technology elements (teleconferencing, electric and alternative-fuel vehicles). The document also identifies freeway and local street corridors in which transportation problems are concentrated, and addresses potential policy alternatives.

Clearly, IVHS technologies are consistent with the 2020 Vision. The IVHS elements must be supportive of the County's policies, particularly as they relate to improving transit use and supporting Transportation Demand Management (TDM) strategies.

2.3 GOALS AND OBJECTIVES

The "top-down" strategy development adopted for this study is driven by the transportation needs of Orange County. The first step is the identification of the goals of the system to be developed. These are then broken down into objectives, strategies and finally techniques, in order to identify a broad range of means for meeting the goals, including technological, institutional and operational, near-, mid- and long-term, and across all transportation modes. This methodology ensures that the solutions are based on the needs of Orange County rather than "throwing technology at the problem."

Eight goals have been developed. These have been based upon the following information:

- Local and Regional Needs
- National goals as identified by IVHS America

The goals and related objectives are summarized in the following section, based on the policy defined by the goals and the different transportation objectives which apply toward each goal.

2.3.1 - Summary of Goals

Based on the issues and direction presented above, the following goals have been identified for the transportation system:

- Increase efficiency (person-carrying capacity) of the Transportation System
- Decrease harmful emissions and overall energy use
- Enhance safety of Transportation System

- Support transportation operations and planning activities
- Improve the quality of life for residents of Orange County
- Minimize costs of transportation improvements
- Allow system to evolve (accommodate growth in elements and technologies)
- Increase robustness (ability to adapt to real-time conditions and constraints)

Achievement of these goals rely on a combination of solutions, both policy-oriented and technological. The development of objectives, strategies and techniques in the following sections will bear this out.

2.3.2 - Objectives

The above goals are accompanied by specific objectives to which the transportation system must be directed. These objectives are summarized in Exhibit 2.1 for each goal described above, and may or may not be related to IVHS technologies.

2.4 DEVELOPMENT OF STRATEGIES

To carry out the objectives presented above, a series of transportation strategies are developed for each objective. As with the higher-level goals and objectives, these strategies are independent of technology and type of improvement, and focus on the actions required for transportation improvements on a Countywide basis. A summary of a1lthe strategies identified is presented in Exhibit 2.2. As is clear from the list, many strategies apply to more than one objective, or are similar in nature. These "family sets" are shown in Exhibit 2.3 and can he combined as shown to form "global strategies." Exhibit 2.4 provides a cross-reference between the global strategies and the Countywide transportation goals. These strategies will serve as the basis for the identification of IVHS and other techniques which are to be used to solve the various transportation problems in the County.

EXHIBIT 2.1
SUMMARY OF GOALS AND OBJECTIVES

Goal	Objective
1. Increase Efficiency	1.1 Manage Demand (reduce number of vehicles in system) 1.2 Manage Flow (direct travel away from congested areas) 1.3 Regain Capacity Following Incident (manage congestion upstream of an incident) 1.4 increase Capacity (alleviate system bottlenecks)
2. Decrease Emissions / Energy Use	2.1 Menage Demand (see above) 2.2 Encourage Fuel-Effcient, Clean Running Vehicles 2.3 Reduce Deviation in Speeds (more constant speeds and flows reduce fuel consumption and emissions)
3. Enhance Safety	3.1 Reduce Number of Accidents 3.2 Reduce Accident Severity (includes both vehicle and infrastructure improvements 3.3 Reduce Secondary Accidents 3.4 Speed Emergency Response 3.5 Enhance General Safety of System (facilitate emergency access, civil defense routing) 3.6 Minimize Impacts of Construction, Maintenance, Special Events and Incidents (reducing traffic flow impedance reduces changes in patterns which cause accidents)
4. Support Transportation Operations and Planning Activities	4.1 Collect Data on System Performance and Usage 4.2 Facilitate Interagency Coordination (improvement of information sharing) 4.3 Increase Productivity of City and Agency Staffs (enhance operations through decision support and coordinated responses which reduce repetitive or redundant activities)
5. Improve Quality of Life	5.1 Enhance Traveler Comfort (reduction of stress due delays, lack of information) 5.2 Improve Traveler Convenience (providing timely, reliable means of reaching destinations) 5.3 Provide Equity Regardless of Socio-Economic Status, Disabilities, Etc. 5.4 Provide an Equitable Distribution of Costs and Benefits 5.5 Enhance Economic Vitality (support of tourism, movement of goods and services) 5.6 Decrease Noise 5.7 Improve Reliability (improve consistency of availability and travel times)

EXHIBIT 2.1
SUMMARY OF GOALS AND OBJECTIVES
(CONTINUED)

Goal	Objective
6. Minimize Costs of Transportation Improvements	6.1 Minimize Non-Recurring Costs (include capital and implementation costs) 6.2 Minimize Recurring Costs (include operations and maintenance costs)
7. Allow System to Evolve	7.1 Allow Expansion to Accommodate Future Population and Geographic Growth 7.2 Allow Expansion to Add System Capabilities 7.3 Allow Modiiis to Meet Future Political and Social Environments
8. Increase Robustness	8.1 Improve Operational Flexibility (function in situations where full system is not available or staff ability to operate system is limited) 8.2 Provide Maintainable System 8.3 Adapt to Changing Traffic Patterns (real-time operational flexibility)

EXHIBIT 2.2

ORANGE COUNTY
IVHS ARCHITECTURE
GOALS, OBJECTIVES & STRATEGIES

Goal Objective Strategy

1 INCREASE EFFICIENCY

1.1 Manage Demand

1.1 .l Transport&on Demand Management

1 .1.2.1.2 Spread the demand (Encourage non-peak travel)

1.1.3 Reduce Demand

1.2 Manage Flow

1.2.1 Decrease Turbulence

1.2.2 Manage Routing in recurring congestion

1.2.3 Manage Routing in Construction/Maintenance/Special Events

1.2.4 Provide Pre-Trip information to Traveler

1.2..5 Provide Information to Motorist in Vehicle

1.3 Regain Capacity *Following Incident*

1.3.1 Preplan for Incidents

1.3.2 Detect Incidents

1.3.3 Identify/Verify Incidents

1.3.4 Respond to Incident

1.3.5 Clear incident

1.3.6 Clear Incident-Caused Congestion

1.4 Increase Capacity

1.4.1 Add Facilities

1.4.2 Eliminate Bottlenecks

2 DECREASE EMISSIONS/ENERGY USE

2.1 Manage Demand

2.1.1 Restrictions on Travel when Air Pollution is High

2.1.2 Transportation Demand Management

2.1.3 Spread the demand (Encourage non-peak travel)

2.1.4 Reduce Demand

2.2 Encourage Fuel-Efficient/Clean Running Vehicles

2.2.1 Economic Incentives/Disincentives

2.2.2 Mandates

2.2.8 Funded R & D into clean energy vehicles/subsystems

2.2.4 Fines for emissions

2.2.5 Highway Speed Emissions Monitor

2.3 Maintain Steady Speeds

2.3.1 Decrease Turbulence

2.32 Manage Routing in recurring congestion

2.3.3 Manage Routing in Construction/Maintenance/Special Events

3 ENHANCE SAFETY

3.1 *Reduce the Number of Accidents*

3.1 .1 Eliminate Infrastructure Hazards

3.12 Decrease Turbulence

3.1.3 Prevent Unsafe Driving

3.2 *Reduce Severity of Accidents*

3.2.1 Eliminate Infrastructure Hazards

3.22 In-Vehicle Safety Measures

3.3 Avoid Secondary Accidents

3.3.1 Warn Driver

3.32 Respond to Incident

3.3.3 Clear Incident

3.4 Speed Emergency Response

3.4.1 Respond to Incident

EXHIBIT 2.2

ORANGE COUNTY
IVHS ARCHITECTURE
GOALS, OB JECTIVES & STRATEGIES

Goal Objective Strategy

3.42 Clear Incident

3.5 Enhance General Safety

3.5.1 Improve Emergency Vehicle Access

3.5.2 Support Civil Defense Plans

3.6 Minimize Impacts of Construction/Maintenance/Events/Incidents

3.6.1 Manage Routing in Construction/Maintenance/Special Events

3.62 Provide Pre-Trip Information to Traveler

3.63 Provide Information to Motorist in Vehicle

3.6.4 Preplan for Incidents

3.65 Detect Incidents

3.6.6 Identify/Verify Incidents

3.6.7 Respond to Incident

3.6.8 Clear Incident

3.6.9 Clear Incident-Caused Congestion

3.6.10 Support Rerouting

4 SUPPORT TRANSPORTATION OPERATIONS AND PLANNING

4.1 *Collect data on system performance and usage*

4.1 .1 Real-time Data Base

4.12 O-D Data based on AVI/AVL/VIPS

4.1.3 Credible data analysii procedures for historical analysis

4.2 Facilitate Interagency Coordination

4.2.1 Data Base Accessible to All Agencies

4.2.2 Enhanced Interagency Communications

4.2.3 Single Facility for Interagency Activities

4.2.4 Open Architecture

4.2.5 Direct Computer-to-Computer Communications

4.3 Increase Productivity of City/Agency Staffs

4.3.1 Real-Time Informatin

4.3.2Interactive/Intuitii Information Display

4.3.3 Decision Aids

5 IMPROVE QUALITY OF UFE

5.1 Traveler Comfort

5.1.1 Assist Stranded Traveler

5.1.2 Manage Routing in recurring congestion

5.1.3 Manage Routing in Construction/Maintenance/Special Events

5.1.4 Provide Pre-Trip Information to Traveler

5.1.5 Provide Information to Motorist in Vehicle

5.1.6 Provide Consistent Travel Times

5.1.7 Provide Information for Tourists

5.2 *Traveler Convenience*

5.2.1 Transportation Alternatives

5.2.2 Mass Transit Schedules and Modes Readily Available

5.2.3 Decrease Turbulence

5.2.4 Manage Routing in recurring congestion

5.2.5 Manage Routing in Construction/Maintenance/Special Events

5.2.6 Provide Pre-Trip Information to Traveler

5.2.7 Provide Information to Motorist in Vehicle

5.3 *Equity regardless of Socio-economic status, disabilities, etc.*

5.3.1 Intelligence in Infrastructure rather than in vehicle

5.32 Multi-lingual, both audible and visual information

5.33 Wheelchair accessibility of mass transit

EXHIBIT 2.2

ORANGE COUNTY
IVHS ARCHITECTURE
GOALS, OBJECTIVES & STRATEGIES

Goal Objective Strategy

5.4 Equitable distribution of costs and benefits
5.5 Enhance Economic Vitality
5.6 Decrease Noise
- *5.6.1* Sound Barriers
- 5.62 Reduce Demand
- *5.6.3* Inspections
- *5.6.4* Noise Sensors Combined with AVI

5.7 Enhance Reliability of System
- 5.7.1 Computer-Based Training
- 5.72 Expert systems for Diagnostics/Maintenance
- 5.7.3 Technology Insertion & Upgrade Program
- 5.7.4 Computer Simulation

6 MINIMIZE COST

6.1 Analyze Life Cycle Cost for Range of Alternatives
6.2 Minimize Non-Recurring Costs
- 6.2.1 Minimize Infrastructure Costs
- 6.2.2 Minimize Detector Costs
- 6.2.3 Minimize Communication Costs
- 6.2.4 Reduce Data Processing Costs
- 6.2.5 Reduce Costs of Signage and Displays

6.3 Minimize Recurring Costs
- 6.3.1 Reduce Maintenance Costs
- 6.3.2 Reduce Surveillance and Monitoring Costs
- 6.3.3 Reduce Info Mgmt and Dissemination Costs
- 6.3.4 Reduce Response Costs
- 6.3.5 Reduce Costs of Toll Collection
- 6.3.6 Reduce Costs of Regulation

7 ALLOW EVOLVABILITY

7.1 Allow Expansion to Meet Future Demand
- 7.1 .1 open Architecture
- 7.12 Communications Capacity

7.2 Allow Expansion to Add Capabilities as Technologies. Funding Available
- 7.2.1 Open Architecture

7.3 Allow Modifications to Meet Future Political and Social Environments

8 INCREASE ROBUSTNESS

*8.*1 Improve Operational Flexibility
- 8.1.1 Fault Tolerance
- 8.1.2 Open Architecture
- 8.1.3 Redundancy

8.2 Provide Maintainable System
- 8.2.1 Automatic Problem Identification
- 8.2.2 Redundancy
- *6.2.3* Modularity

8.3 Adapt to Changing Traffic Patterns
- 8.3.1 Modularity
- 8.3.2 Expandability
- 8.3.3 Relatively Load-Insensitive Design

EXHIBIT 2.3

ORANGE COUNTY IVHS ARCHITECTURE
DEVELOPMENT OF GLOBAL STRATEGIES --
(FAMILY SETS)

Goal/Objective/Strategy	Description	Global Strategy
1.2.2	Manage Routing in Recurring congestion	Manage Recurrent Congestion
2.3.2	Manage Routing in recurring congestion	
5.1.2	Manage Routing in recurring congestion	
5.2.4	Manage Routing in recurring congestion	
1.2.3	Manage Routing in Construction/Maintenance/Special Events	Manage non-Recurrent Congestion
2.3.3	Manage Routing in Construction/Maintenance/Special Events	
3.6.1	Manage Routing in Construction/Maintenance/Special Events	
5.1.3	Manage Routing in Construction/Maintenance/Special Events	
5.2.5	Manage Routing in Construction/Maintenance/Special Events	
1.2.1	Decrease Turbulence	Reduce Traffic Turbulence
2.3.1	Decrease Turbulence	
3.1.2	Decrease Turbulence	
5.2.3	Decrease Turbulence	
1.4.2	Eliminate Bottlenecks	
5.1.6	Provide Consistent Travel Times	
1.3.1	Preplan for Incidents	Develop Decision Support and Response Mechanisms
3.6.4	Preplan for Incidents	
3.5.2	Support Civil Defense Plans	
3.6.10	Support Re-routing	
4.3.3	Decision Aids	
1.3.2	Detect Incident	Enhance Incident Detection and Verification
3.6.5	Detect Incidents	
1.3.3	Identify/Verify Incidents	
3.6.6	Identify/Verify Incidents	
5.1.1	Assist Stranded Traveler	Enhance Incident Response
1.3.4	Respond to Incident	
3.3.2	Respond to Incident	
3.4.1	Respond to Incident	
3.6.7	Respond to Incident	
3.5.1	Improve Emergency Vehicle Access	
1.3.5	Clear Incident	Reduce Incident Duration Through Rapid Removal
3.3.3	Clear Incident	
3.4.2	Clear Incident	
3.6.8	Clear Incident	
1.3.6	Clear Incident-Caused Congestion	
3.6.9	Clear Incident-Caused Congestion	
1.1.3	Reduce Demand	Provide Transportation Demand Management Tools
2.1.4	Reduce Demand	
1.1.2	Spread the demad (Encourage non-peak travel)	
2.1.3	Spread the demand (Encourage non-peak travel)	
5.6.2	Reduce Demand	
1.1.1	Transportation Demand Management	
2.1.2	Transportation Demand Management	
5.2.1	Transportation Alternatives	
2.2.1	Economic Incentives/Disincentives	
5.1.7	Provide Information for Tourists	Provide Pre-Trip Traveler Information
1.2.4	Provide Pre-Trip Information to Traveler	
3.6.2	Provide Pre-Trip Information to Traveler	
5.1.4	Provide Pre-Trip Information to Traveler	
5.2.6	Provide Pre-Trip Information to Traveler	
5.2.2	Mass Transit Schedules and Modes Readily Avilable	
1.2.5	Provide Information to Motorist in Vehicle	Provide En-Route Traveler Information
5.1.5	Provide Information to motorist in Vehicle	
5.2.7	Provide Information to Motorist in Vehicle	
3.6.3	Provide Information to Motorist in Vehicle	
4.3.1	Real-Time Information	

EXHIBIT 2.3

ORANGE COUNTY IVHS ARCHITECTURE DEVELOPMENT Of GLOBAL STRATEGIES (FAMILY SETS)

Coal/Objective/Strategy	Description	Global Strategy
3.3.1	Warn Driver	Support Technologies to Enhance Traveler Safety
	In-Vehicle Safety Measures	
3.1.3	Prevent Unsafe Driving	
5.3.2	Multi-lingual, both audible and visual information	Provide Full Accessibility to All Travelers
5.3.3	Wheelchair accessibility of mass transit	
7.1.2	Communications Capacity	Provide Information and Operational Accessibility
4.2.2	Enhanced Interagency Communications	
4.2.5	Direct Computer-to-Computer Communications	
8.1.3	Redundancy	
8.2.2	Redundancy	
4.1.3	Credible data analysis process for histrorical analysis	
4.1.2	O-D Data based on AVI/AVL/VIPS	
4.3.2	Interactive/Intuitive Information Display	
4.2.1	DataBase Accessible to All Agencies	
4.1.1	Real-time Data Base	
4.2.3	Facility for Interagency Activities	
5.3.1	Intelligence in Infrastructure rather then in vehicle	
4.2.4	Open Architecture	
7.1.1	Open Architecture	
7.2.1	Open Architecuture	
8.1.2	Open Architecture	
8.3.2	Expandability	
8.2.3	Modularity	
8.3	Modularity	
8.3.3	Relatively Load-Insensitive Design	
5.7.3	Technology Insertion & Upgrade Program	
5.7.4	Computer Simulation	
5.7.1	Computer-Based Training	
5.7.2	Expert systems for Diagnostics/Maintenance	
8.1.1	Fault Tolerance	
5.6.3	Inspections	
6.2.3	Minimize Communication Costs	Develop System Features to Enhance Maintainability and Cost Effectiveness
6.2.2	Minimize Detector Costs	
6.2.1	Minimize Infrastructure Costs	
6.2.5	Reduce Costs of Signage and Displays	
6.3.4	Reduce Response Costs	
6.3.6	Reduce Costs of Regulation	
6.3.5	Reduce Costs of Toll Collection	
6.2.4	Reduce Data Processing Costs	
6.3.3	Reduce Info Mgmt and Dissemination Costs	
6.3.1	Reduce Maintenance Costs	
6.3.2	Reduce Surveillance and Monitoring Costs	
8.2.1	Automatic Problem Identification	
2.2.3	Funded R&D into clean energy vehicles/sub systems	Develop Facilities and Technologies Reduce Emissins, Energy Use and Noise
2.2.5	Highway Speed Emissions Monitor	
2.2.4	Fines for emissins	
2.1.1	Restrictions on Travel when Air Pollution is High	
5.6.4	Noise Sensors Combined with AVI	
5.6.1	Sound Barriers	
2.2.2	Mandates	
3.1.1	Eliminate Infrastructure Hazards	
3.2.1	Eliminate Infrastructure Hazards	

Exhibit 2.4
COMPARISON OF GOALS AND GLOBAL STRATEGIES

Goal / Strategy	Increase Efficiency	Decrease Emissions/ Energy Use	Enhance Safety	Support Operations & Planning	Improve Quality of Life	Minimize Costs	Allow System to Evolve	Increase Robustness
Manage Congestion - Recurrent	■	■			■			
- Non-Recurrent	■	■	■		■			
Reduce Traffic Turbulence	■	■	■		■			
Develop Decision Support & Response Mechanisms	■		■	■				
Manage Incidents · Detection/Verification	■		■					
- Response	■		■					
. Rapid Removal	■		■					
Provide TDM Tools	■	■			■			
Inform Travelers - Pre-Trip	■		■		■			
- En-Route	■		■	■	■			
Support Technologies to Enhance Safety			■					
Provide Full Accessibility for All Travelers					■			
Provide Info & Accessibility for All Agencies				■	■		■	■
Develop Features to Enhance Maintainability & Cost Effectiveness						■		
Develop Facilities & Technologies to Reduce Emissions, Energy Use and Noise		■	■		■			

2.5 IDENTIFICATION OF IVHS TECHNIQUES

To define the techniques for improving the transportation system in Orange County, a brainstorming process was utilized, which looked at all possible solutions to improving the transportation system, with the focus being on IVHS-related technologies and policies which could be support through IVHS.

In the course of this Study, the Federal Highway Administration (FHWA) has classified in a Working Paper on IVHS User Services and Functions (September 1992) a number of "User Services" and "IVHS Functional Areas". The intent of the FHWA working paper was to provide a structured process in which the scope of operational test and overall IVHS architectures can be defined. For the purposes of the Orange County IVHS Study, these services and functional areas can be cross-referenced against the results of the Study Team's brainstorming process, in order to establish the role of IVHS in improving the Countywide transportation system.

2.5.1 - User Services

Five areas of user services have been defined; in which the users may be travelers, drivers, transit riders, fleet operators and dispatchers, and transportation management personnel.

- Traveler Information
- Traffic Management
- Freight and Fleet Management
- Public Transport and Emergency Vehicle Management
- other Services

The descriptions of these user services essentially correspond to the definitions for the traditional IVHS categories presented in Chapter 1; traveler information parallels ATIS, traffic management encompasses ATMS, freight and fleet management refers to CVO, and so forth. The primary difference is that the IVHS user service descriptions are oriented towards system functions and features, with little or no reference to the technologies required to achieve these services. A summary of the IVHS user services is provided in Exhibit 2.5. These are related to the global transportation strategies in Exhibit 2.6. It is noted that AVCS services and

Exhibit 2.5 - IVHS USER SERVICES

TRAVELER INFORMATION

- Advisories - dynamic information on congestion, incidents, weather, and other conditions
- Service Information - non-traffic related information describing characteristics and locations of service providers (i.e., "yellow page)
- Trip Planning - delays/travel times for roadway segments and schedule/fare information for transit systems to aid traveller in selecting the optimum mode and route
- Route Selection - a more advanced form of trip planning which optimum route/mode is automatically selected based on traveller-entered parameters (e.g., origin and destination, preference, etc.)
- Location Displays - showing the vehicle's current position relative to the transportation network
- Route Guidance - routing instructions for the traveller to reach a desired destination

TRAFFIC MANAGEMENT

- Incident Management - the rapid detection, verification, response, and clearance of incidents which cause congestion.
- Traffic Network Monitoring - real-time surveillance of the transportation network to identify traffic flow conditions
- Demand Management - strategies to encourage travel during non-peak travel periods
- Traffic Control - strategies which allow for adaption to different traffic pattems and response to demands as they occur (e.g., signal timing, lane use restrictions, ramp metering rates, access control, etc.)
- Construction Management - scheduling of construction/maintenance activities and set-up of construction zones so as to minimize their effects on traffic flow
- Electronic Toll Collection - automatic identification of vehicles and automatic debiting of the appropriate amount from a pre-paid account or other billing arrangement

Exhibit 2.5 (continued)

FREIGHT AND FLEET MANAGEMENT

- Route Planning and Scheduling - making informed routing decisions based on real-time knowledge of roadway conditions and vehicles' locations
- Vehicle and Cargo Monitoring - real-time information on shipment status (e.g., location, delays, temperature of refrigerated cargos, other problems)
- Law Enforcement - retrieval of lost and stolen vehicles
- HAZMAT Monitoring and Tracking - coordination of routes, advance notice to appropriate entities regarding vehicle status, and improved emergency response
- Regulatory Support - speeding up the regulatory process and reducing the required number of regulatory stops (e.g., paperless transactions and recording, transparent borders, etc.)

PUBLIC TRANSPORT AND EMERGENCY VEHICLE MANAGEMENT

- Planning and Scheduling - vehicle scheduling and dispatching in response to passenger's schedule needs
- Transit Vehicle Priority - strategies which reduce transit vehicle delay at traffic control devices (e.g., signal preemption, ramp meter bypass
- Automatic Payment - automatic debiting the appropriate fare from travelers pre-paid account, thereby providing quicker fare collection and a flexible fare structure
- Dynamic Ride Sharing - dynamic formation of carpools, matching drivers to travelers
- Prediction of Arrivals

ADDITIONAL SERVICES

- Traveler Safety/Security
- MAYDAY Transmissions

Exhibit 2.6
RELATION OF IVHS USERS SERVICES TO ORANGE COUNTY TRANSPORTATION STRATEGIES

User Service / Strategy	Traveler Information	Traffic Management	Freight and Fleet Management	Public Transport / Emergency Vehicle Management	Additional Services
Manage Congestion - Recurrent		■			
- Non-Recurrent	■				
Reduce Traffic Turbulence		■			(Automated Vehicle Control)
Develop Decision Support & Response Mechanisms		■	■	■	
Manage Incidents - Detection/Verification		■			
- Response		■		■	
- Rapid Removal	■	■			
Provide TDM Tools	■			■	
Inform Travelers - Pre-Trip	■		■	■	
- En-Route	■		■	■	
Support Technologies to Enhance Safety	■			■	(Automated Vehicle Control)
Provide Full **Accessibility for All Travelers**	■			■	
Provide Info & Accessibility for All Agencies	■	■			
Develop Features to Enhance Maintainability & Cost Effectiveness		■			
Develop Facilities & Technologies to Reduce Emissions, Energy Use and Noise		■	■	■	(Automated Vehicle Control)

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technologies are not generally included in the FHWA's definitions, as these are considered to be farther off into the future and are being treated as a separate category. In the interim, they can be treated as "Other Services".

2.5.2 - Functional Areas and Technologies

The IVHS supporting technologies can be broken down into the following functional areas as defined by FHWA

- Surveillance
- Communications
- Traveler Interface
- Navigation/Guidance
- Control Strategies
- In-Vehicle Sensors
- Data Processing

During the brainstorming process for the Orange County IVHS Study, those technologies necessary to support the required user services are identified. Exhibit 2.7 presents a summary of various technologies included in the above functional areas. These technologies are reviewed in further detail in Chapter 6, "The State-of-the-art in IVHS."

2.5.3 - Relationship of Techniques to Strategies

The IVHS user services can be correlated with the proposed strategies as shown in Exhibit 2.8. As is apparent, most IVHS-related improvements benefit strategies related to congestion management, incident management and traveler information. However, particularly for in-vehicle sensors and other future automated vehicle technologies, the safety improvement factor will become an increasingly noticeable benefit of IVHS.

Potential techniques to be applied for each of the strategies were developed based on the project team's knowledge of available technologies and actions to improve transportation system operations. These are shown in Exhibit 2.8, classified by strategy, and categorized as follows:

EXHIBIT 2.7
IVHS FUNCTIONAL AREAS

Functional Areas	Functions	Typical Techniques
Surveillance	Congestion Management Incident Location/Confirmation Determining Device Status Measurement of Emissions/Consumption Data for Planning Purposes	In-Pavement Detection Overhead Detection Machine Vision Automatic Vehicle Identification (AVI) Automatic Vehicle Location (AVL) Vehicle Probes Weather Closed-Circuit Television Manual Methods (e.g., Cellular Call-In) Smart Cards (Transit Use)
Communications	Exchange Data and Information – Between Vehicle and Infrastructure – Within Infrastructure (Agency-to Agency) – Vehicle-to-Vehicle – Between Infrastructure and the Public	Transmission Types – Data (digital) – Voice (analog and digital) – Video (analog and digital) Media Types – Optical (fiber optics) – Bounded Media (analog/digital) – Twisted-Pair Cable – Coaxial Cable – Unbounded (wireless) media (analog/digital) Microwave Satellite Cellular Spread Spectrum Radio Other Radio

EXHIBIT 2.7 (Cont'd)
IVHS FUNCTIONAL AREAS

Functional Areas	Functions	Typical Techniques
Traveler Interface	Distribute Information to Travelers – Transit and Traffic – Passive and Interactive Displays – Special Events Impacting Travel – Status of Transportation Facilities – Tourist Information	Broadcasting (radio and television) Changeable Message Signs Graphic Displays (interactive) Video Text Broadcast Displays Highway Advisory Radio (HAR) Traveler Advisory Telephone (TAT) Interactive Voice Recognition Systems In-Vehicle Displays Touch Screens
Control Strategies	Improve System Efficiency Redistribute Demand Enhance Traveler Safety	Computer- Based Signal Control Strategies – Traffic-Responsive (pattern matching) – Adaptive (current flow) Freeway Ramp Metering Freeway-to-Freeway Connector Metering Preferential Treatments for Transit, High-Occupancy Vehicles (HOVs) – Metering Bypass Lanes – Exclusive Lanes Reversible Lane Controls Response and Traffic Diversion Strategies Roadway Pricing – Toll Roads – Congestion- Based Pricing Incident Management – Freeway Service Patrols – Call Boxes – Cellular "911" monitoring – Accident Investigation Sites Integrated Freeway-Arterial Control Strategies ("Smart Corridors") [illegible]

EXHIBIT 2.7 (Cont'd)
IVHS FUNCTIONAL AREAS

Functional Areas	Functions	Typical Techniques
Navigation/Guidance	Assist Traveler in Trip Planning Guide Along Route Provide Directions to Destination	<u>Location Devices</u> Global Positioning Satellite (GPS) Dead- Reckoning (compass- based) Signpost (radio transmitters on roadside and in vehicle) Radio Multi – Lateration (transmitter in vehicle, receivers in fixed location) Loran C (hyperbollic radio signals) <u>Displays</u> In-Vehicle Maps and guidance Devices Staic Maps at Public or Private Sites Text Information and Messages Audio Information and Messages
Data Processing	Manage and Evaluate Data Pertaining to System Operations Processing of Information – Vehicle-Devices – Roadside- Devices – Central-Devices	<u>Transportation Operations Facilities</u> – Freeway – Surface Street – Integrated <u>Central Processing Hardware</u> – Processors – Workstations – Video Monitors <u>System Software and Algorithms</u> – Automated Incident Detection – Diversion Algorithms – Neural Networks (many processors, collective computation) <u>User Interface</u> – Real-Time Graphics Display – Graphical User Interface (GUI)

EXHIBIT 2.7 (Cont'd)
IVHS FUNCTIONAL AREAS

Functional Areas	Functions	Typical Techniques
Data Processing (continued)		Data Fusion – Real-Time Data Distribution – Database Organization – Standardized User Interface Environments – Database Security – Geographical Information Systems (GIS – Open Systems
In -Vehicle Sensors	Manage and monitor In-Vehicle Conditions Warn Driver of Unsafe Conditions Perform Corrective Actions in Vehicle	Equipment Status Sensors Vehicle Headway Sensors Electronic Odometers Electronic Compass Driver Fatigue and Performance Monitors Anti-Lock Braking Systems

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EXHIBIT 2.8

KEY

USER SERVICES
TI = Traveler Information
TM = Traffic Management
FM = Frelght and Fleet Management
PT = Public Transport and Emergency Vehicle Management
AS = Additional Services

FUNCTIONAL AREA
S = Surveillance
C = Communications
T = Traveler Interface
CS = Control Strategies
N = Navigation/Guidance
D = Data Processing
I = In-Vehicle Sensors

ORANGE COUNTY IVHS STUDY IDENTIFICATION OF TECHNIQUES

Strategies	Techniques	User Service	Functional Area	Other Improvement
1) Recurrent Congestion Management	In-Vehicle Infromation/Navigation Systems	TI	T/N	
	Pre-Trip Information via CATV, media, kloeks			
	Changeable Message Signs (CMS)	TI TI/TM	T T/N	
	Trailblazer signs for pre-planned alternate routes	TI/TM	T/N	
	On-Ramp Restrictions (e.g., closure, restricted meter rates)	TM	CS	
	Reversible Lanes	TM	CS	
	Signal Synchronization	TM	C S	
2) Non-Recurrent Congestion Management	Integrated freeway-arterial control (Smart Corridors)	TM	CS	
	Signal Coordination (responsive/adaptive)	TM	CS/D	
	In-Vehicle Information/Navigation Systems	TI	T/N	
	Pre-Trlp Information CATV, media, kloeks		T	
	Changeable Message Signs (CMS)	TI TI/TM	T/CS/N	
	'Trailblazer" signs for pre-planned alternate routes	TI/TM	T/CS/N	
	On-Ramp Restrictions (e.g., closure, restricted meter rates)	TM	CS	
	Accident Investigation Sites	TM	CS	Physical
	Upsteam ramp closures	TM	CS	
	Downstream turn-off of ramp metering	TM	CS	
	Hlghway Advisory Radio (HAR)	TI/TM	T	
3) Reduce Traffic Turbulence	Ramp Metering	TM	CS	
	Dynamic Speed Limits	TM	CS	
	Signal Synchronization In response to real-time demand	TM	CS	
	Automatic Tdl Collection (ETTM)	TM	CS	
	Commercial Vehlcb Restrictions	FM	CS	
	Restricted Lane Changes	TM/FM	CS	
	Weigh-In-Motion	FM	D	
	One stop vehicle inspection stations	FM		
	Integrated freeway-arterial control (Smart Corridors)	TM	DCS	
	In-vehlcb speed advisory	TM		
	Adaptive cruise control	AS		
	Variable speedontrol or Influence	TM	CS/I	
	Monitor Traffic Speed wlth probes/VIP's/radar tracking	AS	CS	
	In-Vehicle Information/Navigation Systems	TI	T/N	

EXHIBIT 2.8 (Cont.)

ORANGE COUNTY IVHS STUDY
IDENTIFICATION OF TECHNIQUES

Strategies	Techniques	User Service	Functional Area	Other Improvemen
4) Develop Decision Support and Response Mechanism	Interagency coordination	TM	cs	Policy
	Incident Management Plan	TM	cs	Policy
	Simulations to Develop Mitigation Measures	TM	D	
	Expert System	TM	D	
	Pre-Identified alternate router	TM	cs	Policy
	"Trailblazer" signs	TM	CS/T/N	
	Changeable Message signs (CMS)	TM	CS/T/N	
	information collection	TM	S	
	interagency warnlng procedures (civil defense)	TM	cs	
	Mobile command sysytems (civil defense)	TM	cs	
	Evacuation Router and Response Plans	TM	cs	
	Advise on Availability of Public Transit	TI	T	
	Mobile Highway Advisory Radio (HAR)	TM/TI	T	
5) Enhance Incident Detection and Verification	Call Box	TM	T	
	Cellular 011	TM	T	
	Freeway Service Patrol Roving tow Trucks	TM	cs	
	Roving CHP Vehicles	TM	S	
	Surveillance Helicopters	TM	S	
	Roadway Detection (ioopr, radar, microwave, wide area, etc.)	TM/TI	S	
	Vehicle-Roaddds Communications	TM/TI/FM/PT	C	
	Automatic Vehicle identification (AVI)	TM/FM/PI-	S	
	Vehicle-to-intaetruoutre communlcationr link (panic button)	P-r	C/T	
	Vehicle-to-cdl box oommunlcatlonr link	TM	C	
	In-Vehicle 'May Day' systems	TM/PT	T/I	
	Cloeed-Circuit Television (CCTV)	TM	S	
	Expert Systems (Data Fusion for verification)	TM	D	

EXHIBIT 2.8 (Cont.)

ORANGE County IVHS STUDY
IDENTIFICATION OF TECHNIQUES

Strategies	Techniques	User Service	Functional Area	Other Improvement
6) Enhance Incldsnt Response	Expert Systems (Determine Response)	TM	D	
	Freeway Service Patrol (Rodng tow trucks)	TM	CS	
	Signal Pre-emption for Emergency Vehiciee	TM	CS	
	Accident Investigation Sites	TM	CS	
	Paramedice	TM		
	Hazmat Teams	TM	CS	
	Mutual Aid agreements (emergency services) between agencies	TM		
	Closed-Circuit Televisin (CCTV)	TM	S	
	Portable CCTV for image transmission from incident site	TM	S	
	Interamgency hlgh-speed communications links	TM	C	
	AVI (Load Identification)	FM	S	
7) Reduce incident-Caused Congestion ‘ Through Rapid incident Removd	CHP Team	TM	CS	
	Freeway Service Petrol (Roving tow trucks)	TM	CS	
	row Trucks	TM	CS	
	Hazmat Teams	TM	CS	Service
8) Provide Transportation Demand Aanagsment Toole	Roll Roads/Congestion Pricing	TM	CS	
	HOV Lanes	TM	CS	
	HOV Bypass of Ramp Meters	TM	CS	
	Park & Ride Lots	TM	CS	
	Demand Management Policies	TM	CS	Policy
	Incentives			Policy
	Add Publio Transit Routes	PT	CS	Policy
	Increase Public Tranrlt Frequency	PT	CS	Policy
	Pro-Trip Trandt Info (Real-Time)	PT	T/N	
	Pro-Trip Planning Aide (transit)	PT	T/N	
	Publio awareness oampign			Policy
	Expensive or restrictive parking			Policy
	Subsidization of mass transit fees for empioyeer			Policy
	increase gaeoiine taxes			Policy
	Inform traveler en-route of alternate modes (e.g., park-and-ride for transit)	PT/TI	T/N	
	Pre-Trip Information via CATV/Media on alternate routes	PT/TI	T/N	
	Staggered or flexible work hours			Policy
	Telecommuting			Policy
	Shorter work weeks			Policy
	Decentrailzed/relocated employer8 (shorter commutes)			Policy
	In-Vehicle navigation aids	TI	T/N	
	Audio/Videotext for in-home services (shopping, banking)	TI	T	

EXHIBIT 2.8 (Cont.)

ORANGE COUNTY IVHS STUDY
IDENTIFICATION OF TECHNIQUES

Strategies	Techniques	User service	Functional Area	Other Improvement
9) Provide Pro-Trip Traveler Information	Videotext	TI	T	
	Cable TV (CATV)	TI	T	
	Interactive Kiosks (Publio Places)	TI/PT	T/N	
	Silent Radio	TI	T	
	Media Traffic Reports	TI	T	
	Did-up Telephone Services /Traveler Advisory Telephone	TI		
10) Provide En-Route Traveler information	Hlghway Advisory Radlo (HAR)	TI/TM	TTN	
	Changeable Message Signs (CMS)	TI/TM	T/N	
	Radio Data Systems (RDS)	TI	T	
	In-Vehicle Information/Navigation Systems	TI	N/T	
	Ardval Time info at Transit Centers/Transfer Polnts	TI/PT	T	
	Media Traffic Reports	TI	T	
	Did-up Telephone Services /Traveler Advisory Telephone	TI	T	
11) Provide Traveler Safety Enhsnoement	Changeable Message Signs (CMS)	TI/TM	T	
	Highway Advisory Radio (HAR)	TI/TM	T	
	Automated vehicle oontrol	AS	I/future	
	Incident Response	TM	c s	
	Rapid Removal of Incidents	TM	c s	
	Driver Viaibility Enhancement	AS	I	
	in-Vehicle Warning Syrtemr (fog, accident, slippery road, eto.)	AS	I	
	Detection of driver Impairments (e.g., Intoxication)	AS	I	
	Enhanoed Law Enforcement efforts			Policy
	Education programr (i.e.,licenses, ● peed limits, drinking)			Policy
	Increased Public Awareness			Policy
	Vehicle Airbage	AS	I	
	Passive Seatbelts	AS	I	
	Anti-Lock Brakes	AS	I	
	In-Behicle Coilidon Warning (Object sensors)	AS	I	
	Automatic Braking systems	AS	I	

EXHIBIT 2.8 (Cont.)

ORANGE COUNTY IVHS STUDY
IDENTIFICATION OF TECHNIQUES

Strategies	Techniques	User Se rvice	Functlonal Area	Other Improvement
12) Provide Full Accessibility to All Travelers	Multi-lingual, audio and visual Informalon	TI	T	
	Wheelchair aaccessibility of public transit	TI	T	
13) Provide Accessitillty to All Agencies	Bdc systemIntdllqwri in Infrastructure, not In vehicle	TM/TI	D	
	Red-Time Data Base Accessible to All Agencies	TM/TI	D	
	Distributed Intelligence between field components and agencies	TM/TI	D	
	Distributed Intelligence, functions between local and regional agencies	TM/TI	D	
	Standardized Two-Way Communications Unks Between Agencies	TM/TI	C	
	Origin-Destination data through AVI and AVL for planning purposes	TM/PT	D	
	Credible Historical Analysis Procedures for system data	TM	D	
	Direct Computer-to-Computer Communications	TM/TI	C	
	Centralized Coordination of Interagency Activities	TM/I'I	C S	
	Agencies retain autonomy over own facilities	TM/TI	C S	
	Expert Systems (Diagnostics and mdntenance)	TM/TI	D	
	Local Area and Wide Area Networks	TM/TI	D	
	Computer Simulation	TM	D	
	Interactive/intuitive displays (Graphical User Interface)	TM/TI	D	
	Capacity for expansion by adding modular components	TM/TI	D	
	Flexible data access and spatial data relationships through GIS	TMM	D	
	Redundancy In Communications	TM/TI	C/D	
	Redundancy In Data Processing	TM/TI	D	
	Smart Corridor Strategies (Interagency In nature)	TM	C/S	
14) Provide Maintainable and Cost Effective System	Coordinate infrastructure Installation wlth other pufdic works			Policy
	ProvideCost-Effective Survelliance and Monitoring Equipment	TM/TI	S	
	Provide Cost-Effective Signags and Displays	TM/TI	T	
	Utilize elementsrequiring minimal maintenance	TM/TI	D/C/S	
	Provide Adequate System Back-UpData	TM	D	
	Redundancy In Communications	TM/TI	C	
	Data Base supports multiple subsystems	TM/TI	D	
	User fees charged to media/3rdparties for dissemination	TI	T	Policy

EXHIBIT 2.8 (Cont.)

ORANGE COUNTY IVHS STUDY'
IDENTIFICATION OF TECHNIQUES

Strategies	Techniques	User Service	Functional Area	Other Improvement
5) Support Public Policies to Reduce Emissions, Energy Use and Noise	Highway Speed Emissions Monitor	TM	S	
	Finer for emissions			Policy
	Restrictions on Travel when Air Pollution is High	TM	CS	
	Noise Sensors Combined with AVI	TM	I/S	
	Sound Barriers			Physical
	Mandates			Policy
	Inspections (i.e., mufflers, emissions, leaks)			Policy
	Increase gasoline taxes			Policy

- By User Service
- By Functional Area
- If not directly IVHS-related, classified either as "Policy", "Service" (i.e., non-transportation, specific service) or "Physical" (i.e., physical infrastructure) project

The techniques shown here represent a "toolbox" of improvements from which the specific IVHS elements are identified and the system architecture developed.

2.6 OBSERVATIONS

A careful examination of the techniques in Section 2.5 reveal several recurring themes. These observations have important implications for development of IVHS programs in Orange County.

2.6.1 - Public Policy is a Major Factor

Many of the goals, particularly those related to TDM, emissions, fuel consumption and safety, are supported by incentives, disincentives or public education. These policy issues are to some extent outside the scope of this study, but it is highly beneficial for IVHS programs to be complemented by such policy efforts.

2.6.2 - Additional New Construction Not Essential

Adding lanes or roadways increases capacity, but is expensive. This study does not recommend any new roadway construction beyond that currently programmed Additional enhancements for automated highways would be a longer-term element. Research and development efforts will identify the level of infrastructure improvement required.

2.6.3 - In-Vehicle Equipment

In-vehicle equipment, by its autonomous nature, is outside the scope of the public sector, but the IVHS architecture developed in this study must be capable of supporting the real-time information needs of such equipment. In the near term, in-vehicle information and guidance systems support many of the transportation strategies; the architecture must provide the real-time information that such systems will require. In the longer term, automatic vehicle control, such as automated platooning and steering, will have the potential to sharply increase roadway capacity.

2.6.4 - Real-Time Traveler Information (Pre-Trip, En-Route) is Needed

This information can involve both traffic information and transit information, and can be done either pre-trip or en route. This includes trip-planning aids that encompass public transit, especially if they take into account current or expected roadway congestion. Integration of traffic and transit information can allow the traveler to directly compare travel times between origins and destinations, thus allowing an informed mode choice. En-route information allows the motorist to avoid congestion, and warns of hazards, thus decreasing congestion and increasing safety.For transit, en-route information can assist in making proper and convenient corrections.

2.6.5 - Decreasing Traffic Turbulence will Have Several Types of Benefits

Decreasing traffic flow turbulence (stop-and-go traffic, speed differentials between vehicles) is essential. It increases average speeds, saves fuel and prevents accidents. On freeways, a primary technique is through ramp metering, which provides more controlled merge characteristic s, reducing braking and forced maneuvers. On surface streets, turbulence can be reduced through separate turn bays for both signalized and unsignalized intersections, as well as through the appropriate signal synchronization and timing strategies.

2.6.6 - Clearing incidents More Quickly will Reduce Congestion

Incidents cause for more than half the delay on the roadways. Rapid incident removal (as well as providing aid to stranded motorists) results in substantial delay reductions (modeling done by Hughes estimates savings to be up to 60%) and also saves fuel and reduces the pollutants caused by stopped traffic. It also reduces the risk of secondary accidents caused by upstream traffic suddenly encountering stopped traffic.

2.6.7 - Appropriate Real-Time Traffic Response Strategies are Useful

Appropriate traffic response plans, such as re-routing upstream traffic around an incident, is another technique for relieving incident-related congestion. Minimizing the flow into the incident area saves delay and pollution, increases safety and shortens the duration of lingering congestion.

2.7 RECOMMENDED EMPHASIS

A combination of increased operational efficiency, traveler information and policy measures can have a positive impact on safety as well as reductions in emissions and fuel consumption. There are already a number of examples of programs that manage flow and congestion, and incidentally enhance safety and clean air. For example, Fuel Efficient Traffic Signal Management (FETSIM) projects sponsored by Caltrans throughout the State have smoothed flow by traffic signal synchronization and as a result decreased fuel use by 8.6%. The Chicago Area Expressway Surveillance and Control Project resulted in a 30% reduction in peak period freeway congestion and an 18% reduction in accidents, according to the Illinois Department of Transportation

Thus, the Project Team feels improvements in operational efficiency should be emphasized. However, a major area in which safety must be addressed is in the area of signal pre-emption in support of safety (making the roadways more effective for emergency response). This is a policy which the County Board has adopted. The impacts of pre-emption on traffic operations has not been well-documented in the past, although pre-emptionis an element which, at the federal level, is specifically addressed for funding.

In general, technologies exist to address all of the needs outside the vehicle. For example, inductive loops are an existing technology for detecting vehicles and measured speed. However, this is not to say that detector technology will not evolve, or that it is unnecessary to have trial implementations of other technologies. The implications are that the architecture can be built now to meet current needs, but must be flexible enough to grow as technology evolves. Another implication, based on the agency concerns identified in Chapter 4, is that institutional issues will place greater constraints on the structure of the IVHS architecture than will the technology.

3 Analysis of Network

3. ANALYSIS OF NETWORK

This chapter provides an overview of the Orange County transportation network, in light of current and projected demand data using the County's OCTAM-II network, as well as a review of the various components of the transportation network, including those identified in the Statewide Smart Corridor Study as candidate locations for corridor-type IVHS improvements. The Chapter concentrates upon the physical roadway network. In addition to roadways, public transit system elements also play a key role in the IVHS network. However, as public transport is largely roadway-based (e.g., buses, paratransit, rideshare), roadway improvements will greatly and equally benefit both traffic and transit.

3.1 SUMMARY OF TRAVEL CHARACTERISTICS

In order to assess Orange County's transportation needs and deficiencies for the succeeding twenty year period, JHK & Associates analyzed year 1991 and year 2010 data obtained from OCTAM-II, the County transportation network maintained by the Orange County Environmental Management Agency (OCEMA) and utilized by OCTA

Total daily vehicle miles and vehicle hours traveled, and average speeds within the County' s network of streets, roads and freeways are presented in Exhibit 3.1 below:

EXHIBIT 3.1

1990-2010 COMPARISON OF ROADWAY TRAFFIC CONDITIONS

	Vehide Miles (M)	Vehicle Hours (M)	Average Speed (MPH)
1990	50.23	1.69	29.7
2010	87.79	4.99	18.0
Change	75%	195%	-39%

The figures indicate a forecasted 75% increase in demand (vehicle-miles) will result in a 195% percent increase in vehicle-hours of travel time. This represents an approximate tripling in the average duration of a trip within the County over the next twenty years. This is primarily due to the estimated 3% reduction in speed due to increased travel demand, relative to expected growth in capacity.

As indicated by both the 1990 and 2010 OCTAM networks, arterials represent approximately 44% of the total vehicle miles traveled and freeways represent 51%. (The remaining 5% represents four different facility types within the OCTAM model which can be classified as "other.") Arterials, as represented by the OCTAM model, consist of both primary and secondary arterials.

3.2 CURRENT AND PLANNED CAPABILITIES

Orange County currently has 244 miles of freeways, with 36 miles of HOV lanes as of November 1992. The Caltrans Traffic Operations System Master Plan for freeways calls for a TOC supported by increasing levels of freeway loop detectors, changeable message signs (CMS), highway advisory radio (HAR), closed circuit television (CCTV), freeway service patrol (FSP), incident response teams and fiberoptic communications. Details on the operation of the TOC are given in the TOC Study Final Report[1]. There are also three toll corridors and median toll lanes on two freeways planned for construction. The toll corridors will have elements similar to freeways, including ramp metering, CCTV and CMS. The local OCTA transit operation includes; local bus routes, express bus routes, and new commuter rail facilities. In the planning stages are a fixed guideway and light-rail service.

Some, but not all freeways have good alternate routes on the surface streets. A Statewide "Smart Corridor" Study[2] has identified specific freeway/arterial corridors in which balancing of traffic flows through real-time management and information techniques is beneficial. Approximately 271 miles of surface streets in the County are identified as part of these Smart Corridors. These are also discussed later in this Chapter.

For surface streets, the cities and county (in unincorporated areas and contracted cities) have several levels of traffic management capabilities. These range from local signal control to

1 Orange County TOC Study Final Report JHK & Associates. August 27.1991

2 Smart Corridor Statewide Study, JHK & Associates 1990

arterial master control to, at the highest level, Anaheim's Traffic Management Center, supported by CCTV, CMS, HAR and real-time pm-trip traffic information. Some of the cities have worked together on signal synchronization across city boundaries, one example being Katella Avenue. Similar coordination is planned as part of the County's Smart Street program, discussed later in this chapter.

Projects in Irvine and Santa Ana are developing similar ATMS capabilities to Anaheim, and other cities in the County, including Newport Beach, Orange, Huntington Beach and Mission Viejo, are pursuing upgrades of their existing traffic control systems. OCEMA is pursuing integrated coordination between local traffic management systems as well.

3.3 CONSTRAINTS

Orange County differs from other metropolitan areas in several respects. One is the large number of non-local travelers drawn by Disneyland and other attractions. There is also no single, "true" city center, but rather a number of central business districts (Santa Ana, Fullerton and other more mature areas in the County) as well as newer "edge cities" which offer intensive concentrations of commercial and retail activity. There are a large number of inter-region commuters who live and work throughout the County. This means that many areas experience two-way reaming congestion; there are no clear "in-bound" and "out-bound" directions. The continuing growth in Orange County is generally in the form of major developments that cause changes in traffic patterns, particularly in the East and South County areas.

It may be ideal to predict that all IVHS elements will someday be established on a "global" basis. However, economically and politically speaking, this is highly impractical, and in fact not a necessity. Many elements of IVHS are specifically useful under particular roadway conditions (physical and operational), and may not produce the desired benefits under other conditions, nor may they be necessary for those other conditions.

It will thus be appropriate to define corridors and target roadways, as well as specific global elements, to which IVHS improvements will be directed in the early deployment and medium term periods. For the horizon year (2020) of this study, a less-detailed analysis of needs is more appropriate, due to the rapid advances in technology which are likely in the next several years.

3.4 MULTI-AGENCY SYSTEM OPERATIONS

The various cities and agencies which make up the County are making concentrated efforts to increase the capacity and efficiency of the County's roadways through operational improvements. Virtually every primary roadway within the County is equipped with a traffic signal control system which is capable of operating signals in a coordinated manner.

There has also been a measurable increase in the number of cooperative traffic operation projects being undertaken by two or more adjacent jurisdictions. Several recent interagency traffic signal coordination projects have provided the initial thrust toward increasing the number and magnitude of interagency projects. Additionally, eleven Growth Management Areas (GMAs) have been established in conjunction with the County's Measure M funding process, thus providing an additional forum for agencies to combine efforts in developing solutions to traffic congestion.

The deficiencies within the current network lie in the ability of the various systems to transfer and receive traffic data from neighboring systems. While data can be transferred between systems and components of the same manufacture (e.g., Multisonics, a predominant traffic control vendor within the County), only the newer systems and those currently under design have the ability necessary to transfer data between different systems (including to and from Caltrans). For example, Anaheim has expanded their user interface to capture Caltrans data for information purposes, and similar graphics capabilities are currently available to Irvine. The use of "open interface" for data exchange, system control, and monitoring across different hardware platforms is a new design element, but one which has emerged as a necessity within the IVHS design. To a similar extent, the use of standardized communications is desirable between central systems and different controller-types (e.g., NEMA, Type 170) and of different manufacturers. However, with the multiplicity of agencies and controller manufacturers, this requires a considerable effort on the part of the signal controller industry in developing complete standardization

3.5 IDENTIFICATION OF NETWORK ELEMENTS

Several studies concerned with regional mobility within Orange County have been performed over the last few years. The recommendations of these studies for improvement of the transportation network have been used as a prime source of criteria for identifying an "IVHS Network." These studies include:

- Super Streets (1984) - now known as Smart Streets
- Smart Corridors (1990)
- TOS Master Plan (1992)
- TOC Study (1991)

In addition, numerous locally and regionally significant roadways and event areas are of concern in development of the IVHS network. The addressing of localized mobility problems may still involve multiple agencies, however. Thus, the use of the existing GMAs to address localized mobility problems and recommend appropriate IVHS strategies should be considered. Exhibit 3.2 identifies localized mobility problems which necessitate further analysis.

3.5.1 - Smart Streets

The Smart Street (formerly Super Street) network was developed on the basis of its ability to provide:

- freeway corridor replacements or freeway linkages
- additional capacity in freeway corridors
- high capacity arterials at regular intervals

These were prioritized based on:

- existing and future daily vehicle miles of travel (VMT)
- daily vehicle miles of travel per mile (VMT/mi)

A Smart Street has been defined as a high-flow arterial which provides a variety of measures which eliminate or reduce traffic conflicts. These include roadway geometric improvements such as spot widening: pedestrian, intersection, and turning movement grade separations; and traffic control elements such as signal coordination and removal of on-street parking. Only four of the twenty-one original roadways identified as Super Streets are now scheduled to be upgraded due to funding limitations. These roads, now termed Smart Streets, are Beach Boulevard, Katella Avenue, Imperial Highway and the "Street of Four Names" (consisting of Edinger Avenue, Irvine Center Drive, Moulton Parkway, and Street of the Golden Lantern). Additionally, a fifth road, MacArthur Boulevard, will be upgraded through a separate Program*

In addition to being planned as Smart Streets, portions of Reach Boulevard and Moulton Parkway have been identified as alternate routes to freeways within Smart Corridors, as defined in the Caltrans Smart Corridor Statewide Study (1990).

3.5.2 - Smart Corridors

To define target corridors which have been previously established for IVHS improvements, the Smart Corridor Statewide Study developed for Caltrans is a useful base. Smart Corridors have been identified based on the following criteria:

- Presence of Freeway Congestion
- Limited Freeway Capacity Relative to Demand
- Altemative Parallel Routes
- Accidents and Incident Rates
- Part of Potentially Larger System

These projects generally include traffic-responsive signal system operations, as well as Closed Circuit Television (CCTV), Changeable Message Signs (CMS) and Highway Advisory Radio (HAR). Operations of these elements on surface streets and freeways are coordinated when necessary through the use of Expert Systems which identify appropriate response strategies. However, most of the proposed roadways within the defined Smart Corridors are not yet incorporated into projects.

All Orange County freeways were reviewed for level of congestion and opportunities for implementing Smart Corridor techniques. Reviews consisted of meetings with representatives of regional and local agencies, capacity adequacy ratings as identified in the Caltrans Route Segment Report, published annual congestion ratings, and additional available data.

Alternate routes to the freeways were selected in the Smart Corridor Statewide Study as a result of drive-through studies examining the mutes. The recommended Smart Corridors were developed based on the above data and the corridors were prioritized by estimated benefit/cost ratios. This priority is shown in Exhibit 3.3.

(The I-5 prioritization takes into consideration the benefits to be gained from the current freeway widening project within this corridor, and therefore received a lower ranking than otherwise would have been expected)

3.5.3 - TOS Master Plan

Caltrans District 12 has developed a Traffic Operation System (TOS) Master Plan which details the existing, programmed (funding sources identified), and planned (no funding identified to date) instrumentation of the County's freeways. The defined freeway instrumentation, as well as the prioritization of development within the Master Plan, complements the development of the transportation network as specified by the Smart Corridor Statewide Study. The resultant Preliminary IVHS Network is presented in Exhibit 3.4.

In addition to the freeway segments specified as belonging to Smart Corridors, the TOS Master Plan calls for instrumentation of the remaining freeway segments within the County (Exhibit 3.5, Supplemental M-IS Freeway Segments).

3.5.4 - TOC Study/Tollroads

The Orange County Traffic Operations Center (TOC) Study served as a precursor to the TOS Master Plan in identifying the required level of improvement to the freeway TOS.

In addition to addressing the freeway network, the TOC Study addresses the toll roads planned for Orange County. The toll roads will not be explicitly identified for program development within this study, as these facilities are currently being planned and constructed in

3.6.2 - Causes of Delay

Delay and traffic congestion consist of two components, recurring and non-recurring congestion. Recurring Congestion refers to conditions which occur on a regular basis as a function of normal daily travel patterns and transportation network constraints. Such recurring congestion occurs during peak travel hours regardless of other elements which might add to the traffic flow.

Non-recurring congestion refers to that congestion caused by elements or incidents which do not occur on a daily basis. Many of these events are scheduled, and many including sporting events (i.e., at Anaheim Stadium, Anaheim Arena), Construction, or seasonal traffic (e.g., beach traffic). However, much of the non-recurring congestion refers to unplanned incidents, such as accidents or fuel spills. These incidents, particularly when they cause lane blockages, have a significant effect on congestion. Based on a Incident Management study by Cambridge Systematics (October, 1990), it is estimated that 52% of all delay (in vehicle-hours) on freeways is non-recurring. Similar data has been developed for surface streets.

Although recurring delay can be reduced through a number of "default" operations strategies, including signal synchronization and ramp metering, non-recurring delay tends to have the most severe impact on the roadway network. Thus, the focus of delay reduction must necessarily address incident-related and event-related congestion.

Clearly, most incident-related congestion occurs on the freeways. In fact, past experiments in which a car was intentionally stalled in traffic on a surface street did not result in significant impacts on traffic flow other than at a very localized level. Exhibit 3.7 shows a typical distribution of reported incidents (stalls and accidents) five minutes or longer in duration.

As illustrated in Exhibit 3.8, the roughly 20% of incidents more serious than a shoulder disablement cause approximately 80% of all non-recurrent congestion.

Additionally, in Orange County, a number of event centers generate substantial local as well as non-local travel. Exhibit 3.9 shows, by City, special event traffic occurring either year-long, seasonally, or during the event duration. To summarize, the primary trip generators include:

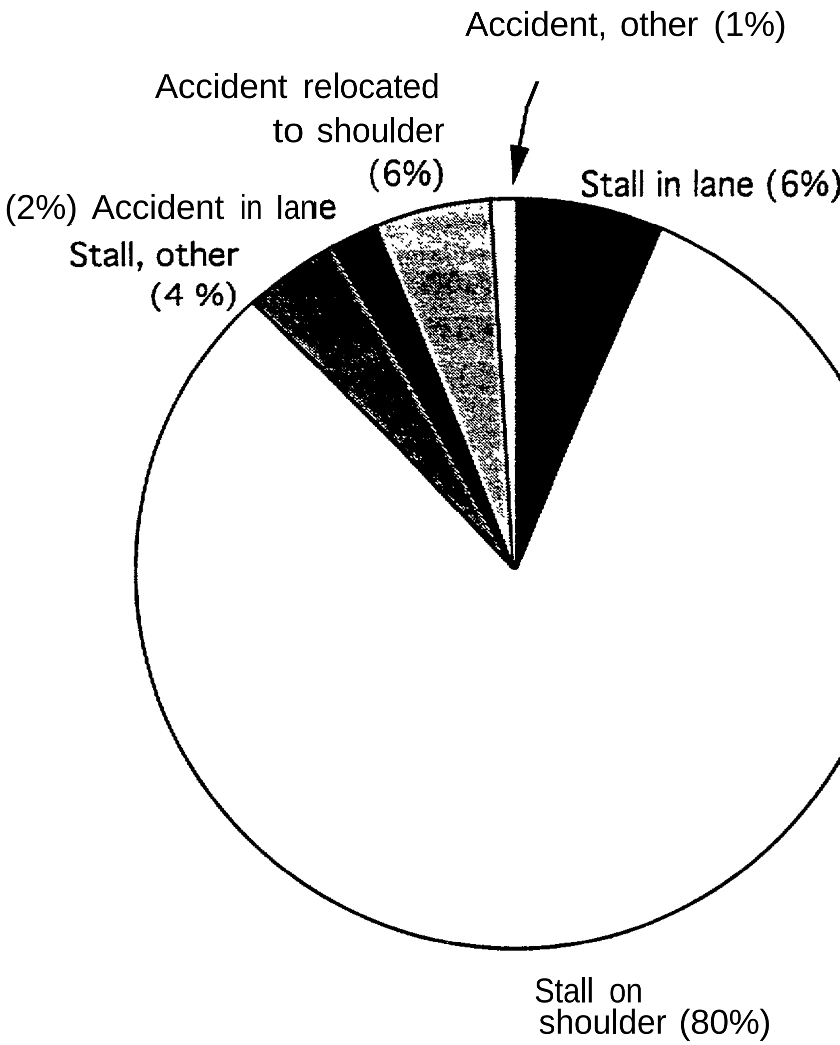


Exhibit 3.7
Typical Incident Characteristics*

*** Stalls and Accidents of 5 minutes duration or greater**

concert with recent IVHS developments, and are being constructed largely with private funds (with public input). However, as the toll roads are anticipated to play a major role in the County's mobility, they will be considered an important part of the overall M-IS network. Exhibit 3.6 depicts the three Transportation Corridor tollways to be constructed and the additional toll lanes to be added to SR-91. Not depicted is the toll road extension of SR-57 to I-405 and SR-73 (the Santa Ana River Viaduct), which is less advanced in development than are the previously defined toll roads.

3.6 ASSESSMENT OF CONDITIONS

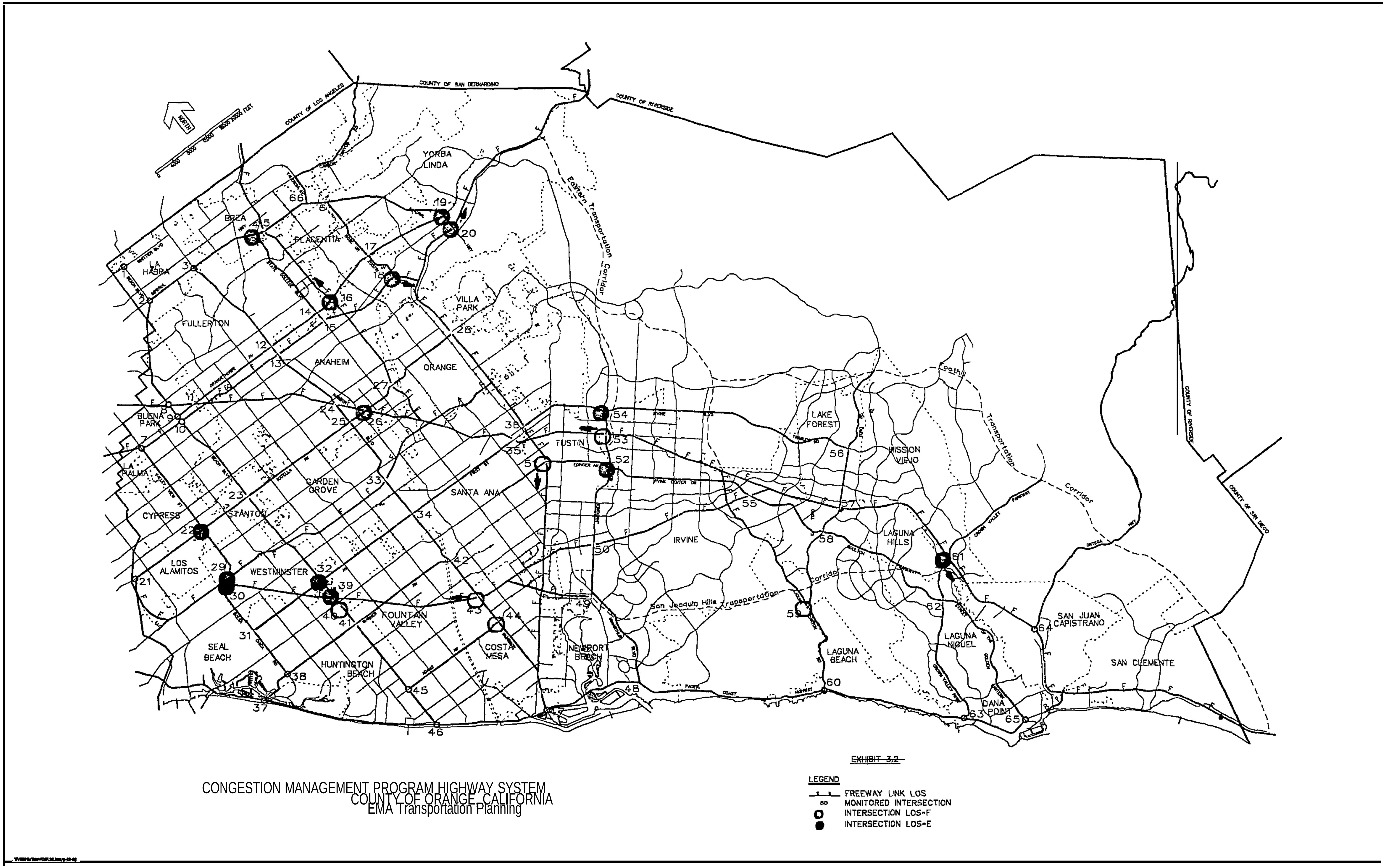
Traffic conditions on the roadway network and for local areas were evaluated on a global as well as a localized basis. For the purposes of this study, these served to reinforce the focus of M-IS improvements as per the strategies identified in Chapter 2.

3.6.1 - Quantifiable Measures of Effectiveness

Several quantifiable measures of effectiveness (MOEs) were applied to the locations identified above. The data reviewed included:

- Capacity adequacy as identified in the Caltrans Route Segment Report.
- Recurrent delay as identified in the Caltrans Annual Congestion Report.
- Volume, volume/capacity, and level-of-service as identified by the Orange County Congestion Management Program (CMP).
- Volume, speed, vehicle miles traveled as identified by the OCTAM model for 1987 and 2010.

No significant changes in the identified IVHS Network resulted from this analysis.



CONGESTION MANAGEMENT PROGRAM HIGHWAY SYSTEM
COUNTY OF ORANGE, CALIFORNIA
EMA Transportation Planning

Exhibit 3.3
RECOMMENDED SMART CORRIDORS
IN ORANGE COUNTY
(From Smart Corridor Statewide Study, JHK & Associates, 1990)

FREEWAY	ARTERIAL STREETS / ALTERNATE ROUTES
I-5 from Oso Parkway to Euclid	Harbor Blvd., Euclid St., Bolsa Ave., Edinger Ave., Dyer Rd., Irvine Blvd., Red Hill Ave., Alton Pkwy., Irvine Center Dr., Moulton Pkwy., Muirlands Pkwy., Trabuco Rd., Marguerite 'Pkwy., Oso Pkwy.
Route 22 from I-405 to Route 55	Garden Grove Blvd., Westminster Blvd./l7th St., Bolsa Ave./1st St., Tustin Ave.. Seal Beach Blvd.. Bolsa Chica St.
Route 55 from I-405 to Route 91	Lincoln Ave., Tustin Ave., Red Hill Ave., MacArthur Blvd.
Route 57 from I-5 to Route 90	State College Blvd., Imperial Highway, I-5 Freeway
Route 91 from Imperial Highway to Beach Boulevard	Orangethorpe Ave., La Palma Ave., Lincoln Ave., Beach Blvd., Santa Ana Canyon Rd.
I-405 from Route 22 to I-5	Bolsa Ave./1st St., Edinger Ave., Warner Ave., Talbert Ave./MacArthur Blvd., Irvine Center Dr., Jeffrey Rd., University Dr., Route 22 Freeway Route 73 Freeway

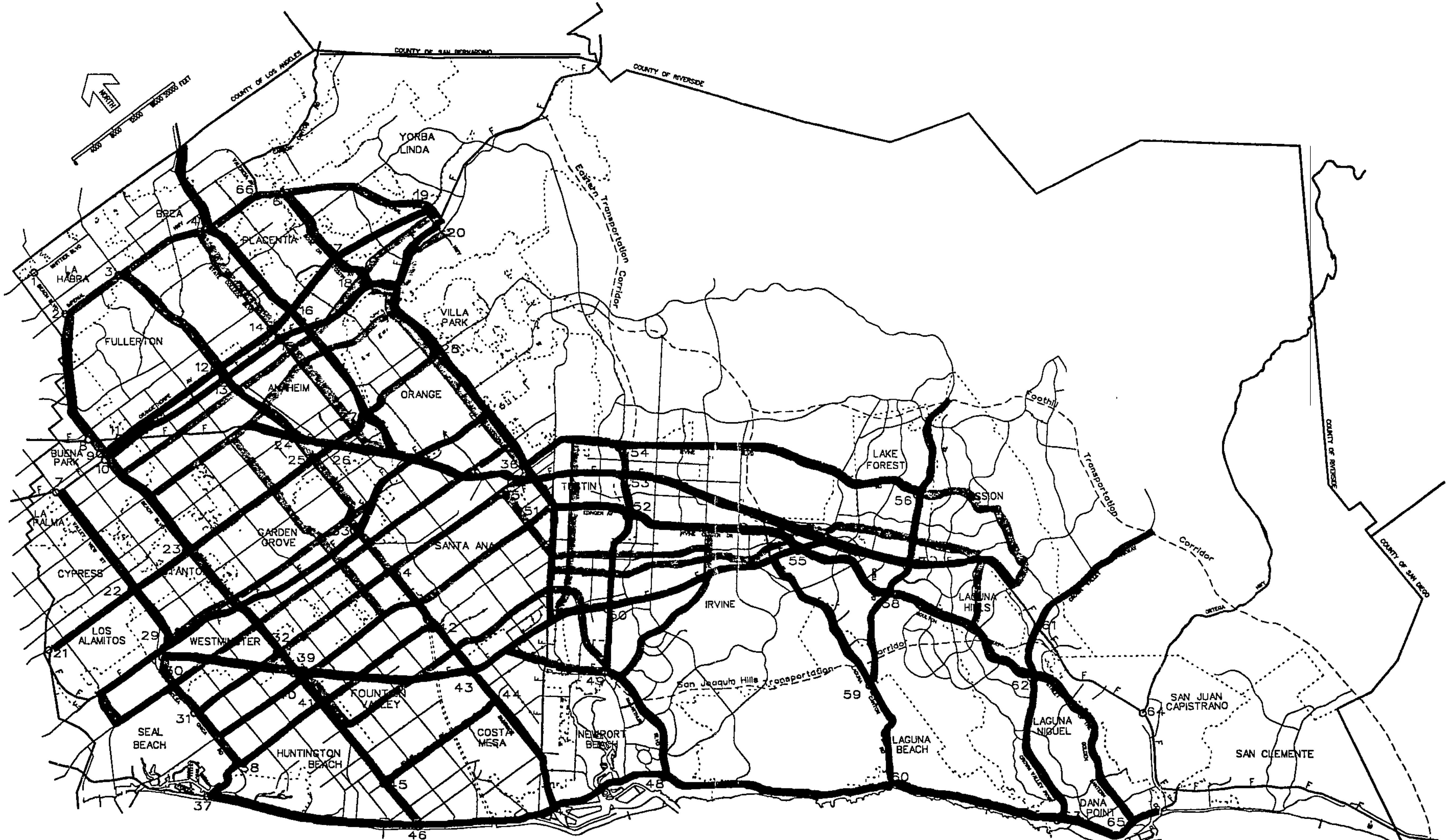


EXHIBIT 3.4

PRELIMINARY IVHS NETWORK

CONGESTION MANAGEMENT PROGRAM HIGHWAY SYSTEM
COUNTY OF ORANGE, CALIFORNIA
EMA Transportation Planning

LEGEND

- FREEWAY LINK LOS
- 50 MONITORED INTERSECTION
- SMART CORRIDOR FREEWAYS
- SMART CORRIDOR ALTERNATE ROUTES
- SUPER STREETS TO BE CONSTRUCTED AND ARE DESIGNATED SMART CORRIDOR ALTERNATE ROUTES
- SUPER STREETS TO BE CONSTRUCTED
- DESIGNATED SUPER STREETS ELIMINATED FROM CONSTRUCTION PLAN AND NOT A SMART CORRIDOR ALTERNATE ROUTE

EXHIBIT 3.5

SUPPLEMENTAL IVHS FREEWAY SEGMENTS

LEGEND

FREEWAY LINK LOS

50 MONITORED INTERSECTION

FREEWAY SEGMENTS NOT DESIGNATED SMART CORRIDOR LINKS

CONGESTION MANAGEMENT PROGRAM HIGHWAY SYSTEM
COUNTY OF ORANGE, CALIFORNIA
EMA TRANSPORTATION Planning

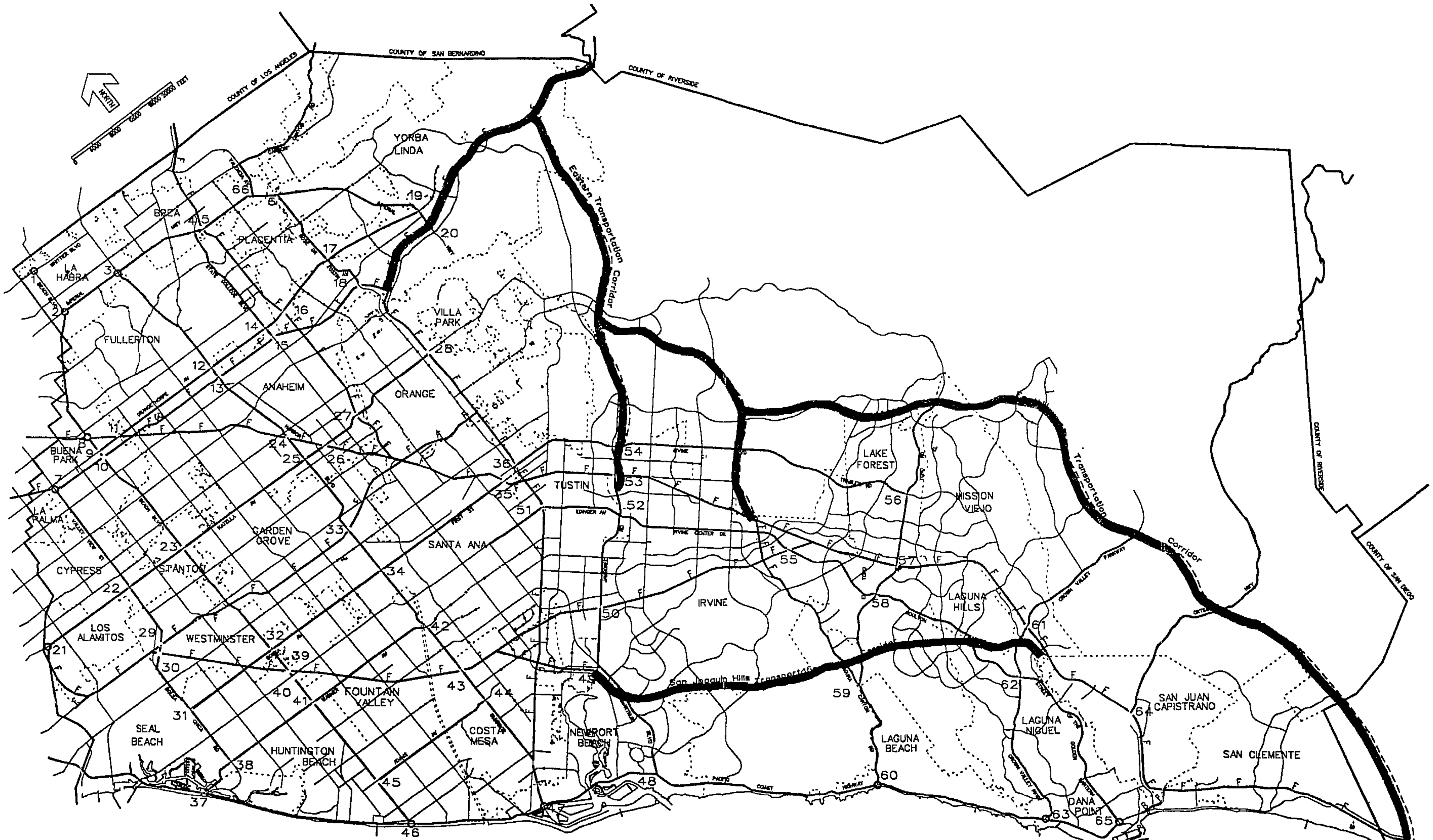


EXHIBIT 3.6

TOLLROADS

LEGEND

FREEWAY LINK LOS
SO MONITORED INTERSECTIN
TOLLROADS

CONGESTION MANAGEMENT PROGRAM HIGHWAY SYSTEM
COUNTY OF ORANGE CALIFORNIA
EMA Transportation planning

- Pacific Amphitheater
- Orange County Fairgrounds
- Irvine Bowl (Laguna)
- Knotts Berry Farm
- Irvine Meadows
- UC Irvine
- Shopping Malls
- El Toro Air Station
- the Pacific Ocean
- Disneyland
- Anaheim Stadium
- Anaheim Arena
- CSU - Fullerton

The majority of these event generators are located within identified Smart Corridors and/or along designated Smart Streets.

3.7 PUBLIC TRANSIT AND CARPOOLING

Alternate transportation modes (bus, rail, carpools) were explicitly considered in conjunction with the identified M-IS Network as were bus and high occupancy vehicle (HOV) facilities considered as stand-alone components of the network. Information regarding current and planned transit services was gathered from OCTA publications.

The existing and planned intercounty bus routes are heavily reliant upon the identified IVHS Network and consequently, the Orange County Transit Authority's transit operations center has been identified as an information center in conjunction with the Smart Corridors. Additionally, the commuter rail lines and HOV lanes are similarly consistent with the identified Smart Corridors, and thus the IVHS Network.

Alternate transportation modes are discussed in greater detail in Chapter 9, "The Master Plan," and in the "Action Plan" which accompanies this document.

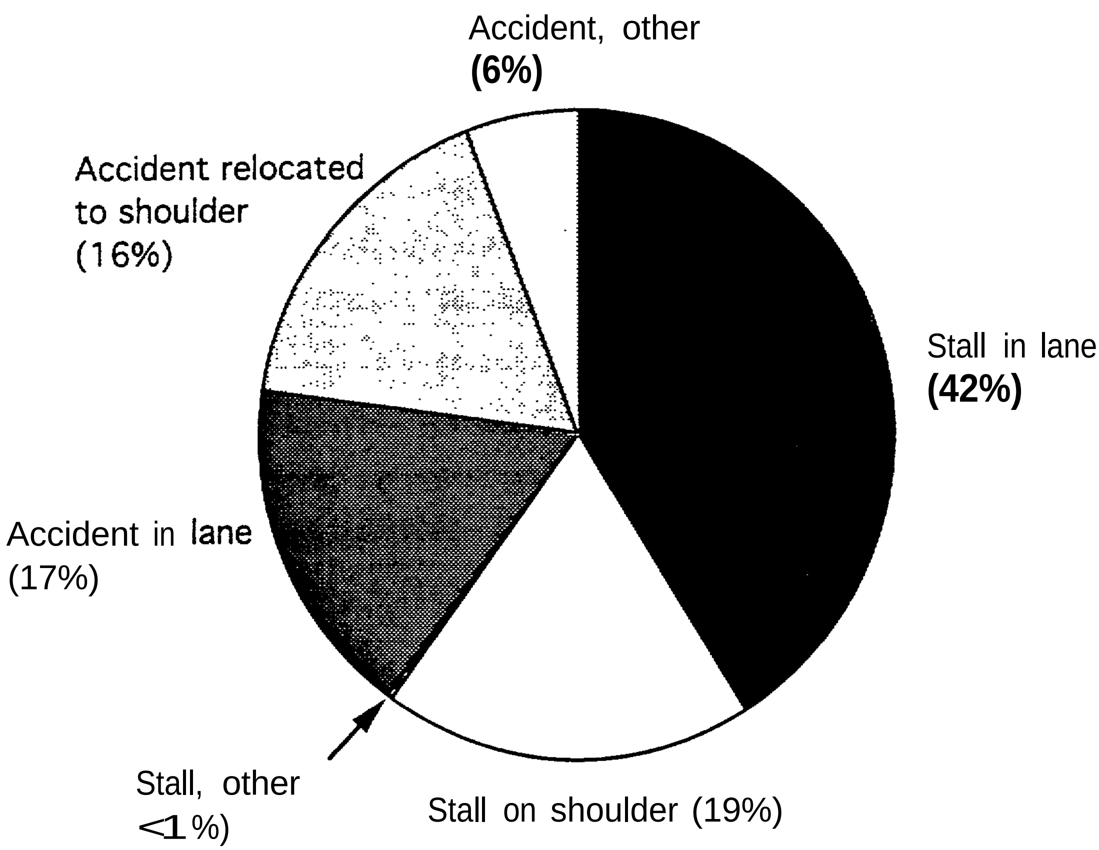


Exhibit 3.8
Typical Causes of Non-Recurrent Delay
(Incident-Related)

EXHIBIT 3.9 SPECIAL-EVENT TRAFFIC BY CITY

	Duration of Heavy Special-Event Traffic			
City	Year-Long	Summer	<3 weeks per Event	Little or No Traffic Generated
Anaheim	Stadium Convention Center Disneyland Arena (1993)			
Buena Park	Knott's Berry Farm	Beach		
Westminster	Little Saigon		Tet Festival	
Garden Grove	Little Saigon		Strawberry Festival Shakespeare Festival	
Huntington Beach		Beach	10K runs	
Laguna Beach		Beach	Sawdust Festival	
Newport Beach		Beach Cruising	Decorated boat parade Other festivals	
Costa Mesa		Pacific Amphitheater Beach	Orange County Fair Christmas shopping, South Coast Plaza	
Seal Beach		Beach	Volleyball tournaments Sandcastle contest	
Dana Point		Beach		
Laguna Hills			Christmas shopping, Laguna Hills Mall	
Santa Ana			Christmas shopping, Main Place	Parades
Yorba Linda			Nixon Library events	Fiesta Days Bicycle races
Brea				---
Cypress				Los Alamitos Racetrack
Fountain Valley				Mikes Square Park events
Fullerton				CSUF sports
Irvine	UCI Special Events	Wild Rivers Irvine Meadows Amphitheater	El Toro Air Show	---
Laguna Niguel				---
La Habra				---
La Palma				---
Los Alamitos				---
Mission Viejo				---
Orange				---
Placentia				Heritage Days Parade
San Clemente				Beach
San Juan Cap.				Beach
Stanton				---
Tustin				Parades, Races
Villa Park				---

4 Institutional Issues in IVHS Implementation

jhk & associates

4. INSTITUTIONAL ISSUES IN IVHS IMPLEMENTATION

4.1 INTRODUCTION

This chapter identifies the institutional and operational issues in Orange County as related to transportation management, communications, transportation planning and overall transportation responsibilities. The key issue is the extent to which interagency cooperation is required and the roles which various agencies must play in this regard. It was determined at an early stage of the process that many of the defining characteristics of an IVHS system architecture would depend upon this institutional structure.

4.2 DISCUSSION OF ISSUES

In order to identify institutional issues relative to the deployment of M-IS, face-to-face interviews were conducted with, and follow-up questionnaires distributed to, the following:

- 31 Local Cities (Listed in Appendix A-l)
- Region-wide Agencies within Orange County (Listed in Appendix A-2)

  Caltrans District 12
  OCTA
  Orange County Environmental Agency (OCEMA)
  Others

- Neighboring Agencies (Listed in Appendix A-3)

  Caltrans Districts 7,8 and 11
  Long Beach Transit
  Los Angeles County Metropolitan Transportation Authority (LACMTA)
  Others

- Private Sector (Listed in Appendix A-4)

  Event Centers (tourism, sports, convention)
  Shopping Malls
  Major Employers

Consensus

- Use of a pre-emption for transit vehicles was perceived to be of little benefit, due to the frequent stops required for transit vehicles.

It was suggested that a regional preemption demonstration project or perhaps a computer modeling effort, is needed to prove the effectiveness of pre- emption as a traffic management tool.

4.2.2 - Incident Management and Freeway Construction Projects

Most of the agencies raised issues of concern with respect to incident management:

Local-Level Comments

- Cities would like to see Caltrans take the initiative in approaching the Cities in order to accomplish joint incident management strategies.
- Cities would like improved information about both freeway construction projects and incidents on the freeway in terms of their impact and duration.

Regional-Level Comments

- Better coordination and planning between agencies and cities is necessary to ensure that all parties understand roles and responsibilities for incident management. Planning is also necessary to address diversion routes.

  California Highway Patrol (CHP) is interested in the use of enhanced or new technologies that will help improve incident response time. However, due to costs and the reliability of some sources, the current policy of verifying an incident before emergency vehicles are dispatched must prevail.
- Additional written agreements defining procedures for incident management are not wanted and may, in fact, lessen the ability of responding agencies to deal with an incident in the most responsive manner.

- Cities desire a means to improve the interagency negotiation process with Caltrans in agreeing to the content of CMS and HAR messages and any special permits associated with ramp restrictions, roadway closures, or other areas of coordination.

- CMS and HAR messages are subject to two major local concerns. One is how to structure messages for effective communication to motorists. The other is whether messages should be used for non-traffic messages (i.e., promoting the local economy by offering information about local commercial attractions).

Most of the regional agencies believed that special events are handled adequately, but they did have suggestions for the resolution of the issues raised. The issues and recommendations included the following:

Regional-Level Concerns

- Agreements are beneficial, but not necessary as long as every affected agency is involved in the planning of an event. A standardized notification procedure for special events would most likely overcome the few problems that do occur; and

- Lead agencies should be identified for all special events. For consistency, and due to the local nature of many events, most indicated that the cities should be the lead agencies in the planning of special event traffic management.

- HAR is a system which is plagued by poor transmission quality, poorly scripted messages and a lack of real-time information; and

- Caltrans, while recognized as the best regional source for real-time information, is not perceived as being the best entity to operate HAR.

- OCTA may follow-up on the efforts of Calrans District 11 (San Diego area) to privatize the real-time broadcast of HAR. The success of this effort may set a precedent for the operation of HAR in other districts. District 12 currently is using a private contractor to broadcast HAR messages as well, except these are generally not done in response to real-time congestion.

- CMS must prove its credibility by providing information when and where it is most useful, and in a format that is easily understood;

- The public may not be open to the idea of CMS on surface streets, especially near residential neighborhoods.

C. Lead Agency

- Creation of an M-IS leadership group supported by OCTA. This would probably need to be formed from within the existing committee structures. It would need to draw on both technical and policy expertise and would be accountable to the TAC. The mission of the group ought to be to take the initiative and act as a catalyst for promoting MIS policies. The group would be responsible for taking a pro-active role in improving relationships and understanding between the cities and Caltrans.

D. Caltrans

- The Cities desired that Caltrans consider a means of improving communications and understanding between staffs of Caltrans and the Cities. A proposed option would be for them to form a small group of technical staff with good communications skills who would be given an extended mission of working with the cities on a project basis. The intent would be to foster understanding on both sides and find innovative solutions which would allow the full implementation of the capabilities of IVHS technologies. (Note: Caltrans has recently proposed a liaison to work with local agencies.)

E. Discussion of Hardware

- The Cities desire an improved information flow on advancements in hardware and software, including costs, maintenance information and interagency compatibility. OCTA, through the Signal Roundtable, should provide the leadership role in providing information to agencies, and assisting the Cities in providing the ability to share traffic information (either importing or exporting data).

<u>Regional-Level Comments</u>

- Regional-level concerns about exchange of traffic information vary depending on the agency. OCEMA is supporting the development of a standard data exchange process between traffic control systems, working with manufacturers as necessary in development of standard data links. Caltrans supports the use of Type 170 Controllers at the local level as a means to standardize traffic control and field communications.

- Perception of local agencies is that providing buses with real-time data or information for riders, as well as quipping buses with Automated Vehicle Location (AVL) probes to ascertain location, would require monitoring and control systems which are beyond the current capabilities of local agencies.

Regional-Level Comments

- OCTA expressed an interest in coordinating transit information and sharing this information with other agencies. In turn, the OCTA transit operations center would utilize real-time traffic operations data to assist in managing transit.

- A strong interest exists in incorporating commuter rail information, including schedules and real-time train location, into any traveler dissemination capability proposed.

4.2.6 - Air Quality and IVHS

In short, the South Coast Air Quality Management District (SCAQMD) will be supportive of any measures which are going to have a positive impact on traffic flow and resulting vehicle emissions. They will also be supportive of any public information which helps commuters choose not only the least congested route, but more particularly information which helps commuters select an alternative mode of transportation.

4.2.7 - Commercial Vehicles

As most commercial traffic in Orange County is related to trucks on freeways as well as some rail freight, the perception was that commercial transportation (freight and fleet management) could be best handled through federal and statewide programs. The only local-level issue arising from commercial vehicles involves mobility in communities bordering industrial areas. For example, the City of Buena Park is specifically concerned about overnight truck parking. This issue arises due to the lack of truck stops in the Los Angeles/Orange County area. Improved traveler information capabilities would be useful in this regard, particularly those tailored to commercial vehicle operations.

- Overall, shopping mall management did not perceive a great need for IVHS projects. However, they might participate in an IVHS project if it could be demonstrated to benefit their facilities.

- The employers were interested in certain aspects of MIS, but felt that most elements were not appropriate at the work site. One employer was concerned that many M-IS elements discouraged ridesharing which is the opposite of their goal for meeting the AQMD's employer traffic mitigation policy (Regulation XV).

- Comments concur on the importance of the commercial radio broadcasts.

4.3.3 - Summary of Media Issues

A number of radio and private traffic information services were contacted, and the interviewees expressed the following:

- The public who listen to the commercial radio stations for their traffic information will benefit directly from any improvements that can be made to those broadcasts, from improvements in the quality of data available to the traffic information services. Encouraging yet further cooperation between Caltrans and these agencies working as a public private partnership would seem to be of benefit to all concerned.

- Broadcasting traffic information effectively in an understandable and useful manner is a task for professional broadcasters. It is a task that will become only more challenging if route advisory information were to be added to it.

- It is too early to evaluate some of the route advisory systems but their usefulness in principle, seems evident.

4.4 IMPLICATIONS FOR DEVELOPMENT OF IVHS PROGRAMS

The interviews conducted by the Project Team raised several key points that have implications for the design of the overall IVHS architecture for Orange County. The following represents a "consensus" with regard to the issues presented above, such that the M-IS programs can accommodate the institutional concerns and agency structures.

Needs and interests vary greatly city-to-city

Cities throughout the County have reported a wide range of capabilities that reflect their varying needs. Amaheim, with Disneyland, the Stadium, Arena, and convention center, manages heavy vehicle and pedestrian traffic on an on-going basis from a centralized Traffic Management Center (TMC). A number of other communities are primarily residential, and their only traffic concern is reserving their streets for local traffic.

The agencies wish to maintain their autonomy

No agency in the County expressed interest in turning over all transportation management to a single County-wide control facility, although there was general interest in exchanging Countywide information. An example of this was the subject of signal pre-emption for emergency vehicles. There were varying levels of interest in preemption, but an underlying assumption is that this is a local issue since the emergency vehicles operate locally. (The exceptions are for those cities that contract to Orange County Fire Department for emergency services.) The point was made repeatedly that it is neither necessary nor desirable to coordinate the entire region. For example, the timing of synchronized signals is driven by the most critical intersection in the system, which means operation in areas remote from that intersection will be suboptimal. The Katella Avenue Coordination Project, one such interagency optimization program, has succeeded by coordinating local systems rather than by providing overall control of the entire length from one central facility.

A major desire in maintaining autonomy is to maintain control over selection of traffic signal controllers and central control systems. Many cities are satisfied with the sole-source procurement process, and felt that any sharing of control capabilities and information needs to be done through working with the manufacturers.

4.4.2 - Wish List

The agencies expressed interest in several types of program elements to be incorporated into Countywide M-IS programs.

Interjurisdictional cooperation

The success of synchronized signal projects has interested agencies in furthering cooperation across jurisdictional lines. Many agencies are concerned about instances in which traffic was diverted from another jurisdiction and they were not notified. They would like to see a better integration of freeways and surface streets, with advisories (CMS, HAR, media) presented on one roadway when problems are on another (e.g., construction on Beach Boulevard, suggest alternate exit: accident on freeway, suggest alternate route to next on-ramp).

Local information (e.g.. portable CMS for beach parking

Several cities have local traffic problems that could be supported by better traffic information dissemination capabilities. In particular, the beach communities want to be able to direct the often heavy beach traffic to parking areas. There are also occasional special events that could benefit from enhanced local traffic information.

4.4.3 · Constraints and Concerns

The agencies expressed concerns on limitation which could impact their ability to support or contribute to a Countywide IVHS implementation.

Very limited staffs for operations and meetings

All of the agencies work with very limited staffs. A number of cities are fiscally constrained from hiring additional staff. Some cities have a traffic engineering department consisting of only one person. A number of agencies contract their traffic engineering services to consultants, some of which work for multiple agencies. In addition to day-to-day operations and planning, there are many meetings of various groups. There is widespread concern that the IVHS architecture may require the formation of yet another committee.

4.5.2 - Decision Aids to Ease Operator Workload

The limited staffs indicate a design requirement to make the Operator's job easier. This means that the data must be easily interpretable, and that the system monitor itself, alert the Operator through alarms or messages (freeing the Operator to concentrate on his other jobs), and make recommendations utilizing a decision support apparatus such as an expert system. For example, Caltrans' TOS Master Plan states, "One problem ramp meter operation presents is to have sufficient personnel with the required expertise to monitor, update and change the operation of ramp meters." The intent would be for this expert system to incorporate the necessary expertise to take over much of this type of work and free up the personnel.

4.5.3 - Universal and Automated Sharing of Graphical Traffic Information

Currently, traffic information is passed on an ad hoc basis. To ensure that all interested parties get the information they need, the system should collect all data and disseminate it automatically. In that way, all agencies will receive the information about, say, an accident in an adjacent community, even if the responsible agency is too busy to notify them. It is recommended that this information be presented in a graphical manner for ease of interpretation.

4.5.4 - Local Needs Vary and thus the System Must be Flexible

The needs of the local areas vary greatly, and the corresponding traffic centers should be built to meet these needs. This indicates a flexible structure that accommodates major traffic management centers as well as simple control of a small number of signals. Further, rerouting capability makes sense only where there are alternate routes of sufficient capacity.

4.5.5 - Provision for Sharing or Remote Monitoring (off-hours or in the field)

Because of limited staff, traffic monitoring is not done 24 hours a day, or even during all normal work hours. Traffic staff are often working out in the field. It may be mutually beneficial if cities could agree to trade off monitoring of each other's areas, possibly allowing mutual control, and/or notification in the field This should be supported by a means of paging or otherwise contacting people in the field and giving them access to system information. Furthermore, the capability to take over monitoring and/or control of other areas is important for emergency preparedness (e.g., in case of a major earthquake).

4.5.6 - Ongoing Technical Advice and Evaluation Needs to be Included

An important part of the overall IVHS implementation will be input on technological advances and trials of new products throughout the country. A specific person at the regional level could be designated to make recommendations as the system evolves.

4.5.7 - The Institutional Issues Outweigh the Technical

As seen above, the technology issues for “smart roadways” (though not yet “smart cars”) are all solvable. While the technology will evolve, and more cost-effective solutions will become available, reasonably priced products exist now. On the other hand, the issues of sharing information and control are complex and the solutions are not obvious.

Do the benefits justifv the costs?

There is concern that an M-IS architecture could be high-technology "window-dressing" and will not improve traffic. Money is a major constraint and agencies are concerned about measurable benefit relative to the expense. There is also concern about operational costs in terms of training and operations, and that overly complex equipment could make response slower and more difficult. Vandalism, maintenance, and reliability need to be taken into account.

If capacity is insufficient, shifting it will not imrove things

In some areas, there are no viable alternate routes; either there are no parallel roadways, or the parallel roadways are congested. In such cases, it is agreed that any attempts to reroute traffic will only lead to motorist frustration and will not help congestion. A number of agencies feel it is unnecessary to present information that says a roadway is congested when it is obvious to the traveler, and there is nothing that can be done with the information. There is also concern about providing all travelers with the same information, thus shifting all traffic onto another roadway which is then at least as congested as the previous one.

4.5 IMPLICATIONS FOR ARCHITECTURE DESIGN

The institutional issues discussed above have major implications for IVHS program development. It is apparent, in fact, that the institutional needs have a greater impact on the IVHS architecture than does the future direction of IVHS technology. The following are the major implications of these issues on the design of the architecture.

4.5.1 - Regional Control with Global Coordination

There is on one hand a very strong interest in local control, and on the other interest in information about and coordination with other jurisdictions. This says that the architecture should support direct control (e.g., signal timing) at the local level, while allowing all access to county-wide information, and supporting coordination across jurisdictional lines.

Technical assistance and advice

Several agencies are interested in learning more about advanced technologies and trials of new equipment. There seemed to be an interest in developing and improving projects, but many agencies feel they do not have the background nor the time to evaluate the options. It is felt that additional resources available outside the local agency (e.g., at the OCTA or Caltrans level) would be desirable.

Real-time notification regarding incidents that affect them

Traffic diversions on the freeway, a special event, or major construction in a neighboring city are examples of events that potentially impact traffic on surface streets and freeways. Notification of all agencies involved or impacted concerning these events is essential to providing responsive real-time traffic management.

Improved signal control and coordination for enhanced flow

The main concern of the cities is surface street flow. The agencies mainly enhance this flow through coordinated signal control, often with centralized monitoring or control facilities. The cities are aware of the benefits accrued from coordinating across city lines and are interested in expanding it where appropriate. There is also some interest in traffic-responsive signal control based on real-time conditions.

System monitoring

Timely notification of equipment failures, congestion, and incidents would enhance traffic operations. Often, agencies do not know about system failures or specific events until they are notified by the police or malfunctions are identified in the field by maintenance staff.

4.4.1 - Interagency Concerns

Cities can and do work together

The coordination across city lines that will be necessary for the successful operation of the system is already underway in several areas. A prime example is the Katella Avenue signal synchronization project. The cities involved (Anaheim, Garden Grove, Stanton, Los Alamitos, Cypress) consider it a success and a good learning experience, and the Cities in general are interested in more projects of this type. The major problems were in reaching agreements on how to coordinate. While there were some instances of inter-city disputes, generally involving funding (i.e., obtaining traffic mitigation funds from neighboring expanding communities), there were many more success stories of shared resources and coordination.

The cities want more information/cooperation from Caltrans

Although several of the cities feel they have good working relationships with Caltrans, a number are concerned about notification from Caltrans concerning real-time diversions onto local streets as a result of incidents. There have been reported instances in which Caltrans failed to notify them of incidents and resultant traffic diversions, even though the Cities were ready and able to handle traffic diverted from the freeways onto their streets if they had been notified Some also said that it is difficult for the cities to reach the appropriate people at Caltrans. In addition to better, more timely information flow, they would like the cities' needs to be better-addressed in Caltrans' plans, for example, the effect of restrictive ramp metering rates on city streets. Also, the Cities have information that is useful to Caltrans (e.g., surface street construction that is causing a backup on the freeway) that they would like to share. Thus the need for interagency coordination on an institutional as well as real-time operations level emerges.

4.3 PRIVATE SECTOR ISSUES IN IVHS IMPLEMENTATION

In this section, the intent is to assess the role of the private sector of their needs in the area of traffic information. Also evaluated is the extent of their need for improved information flows as well as the means to make real-time information more readily available at the major trip generators.

A secondary task in the private-sector interviews was to provide information about the potential elements of IVHS. Representatives of, and spokespeople for, the management of a number of major event centers in the County were contacted and interviewed. TWO local Transportation Management Associations (TMAs) were represented as were a number of large, geographically diverse employers. The media proved to be extremely interested in the topic of IVHS and interviews were held with a number of commercial radio stations and private suppliers of traffic information.

4.3.1 - Summary of Event Center Comments:

Event centers, including Disneyland, Anaheim Stadium, and other sites were represented. To summarize:

- The event center interviewees had an overall favorable attitude towards the use of IVHS technologies. They seemed very cooperative and willing to work with new ideas.
- They currently work to coordinate traffic management with the cities and with Caltrans but are probably limited in the use that they could make of real time information at their sites.
- As with other groups they feel that commercial radio plays an important role.

4.3.2 - Summary of Commuter and Retail Traffic Issues

Managers of retail centers and employer transportation coordinators were interviewed, and expressed the following:

- Agreements are needed for specific agency roles and responsibilities in traffic management, especially along corridors where diversion routes are not easily identified and incidents affect multiple jurisdictions. This is in contrast to regional-level comments on incident management in which there was a desire to minimize the paperwork.

- Agencies are concerned with the costs and liabilities associated with assisting in traffic management and incident response outside of their jurisdictions.

- Caltrans prefers to work with groups of agencies rather than individual agencies, in terms of developing interagency traffic management strategies.

- CHP and Caltrans were considered to be best suited to serve as lead agencies due to their regional authority and access to real-time traffic information.

- It was felt a principal contact person within each agency would benefit interagency cooperation. It is noted that Caltrans has prepared such a liaison to work with local agencies.

4.2.5 - Transit and IVHS

With the exception of the Central County area (Santa Ana, Anaheim, etc.), transit ridership is relatively low throughout the County. However, new services are being developed that will enhance transit availability and service frequency.

Issues discussed with regard to public transit and M-IS are presented below:

Local-Level Comments

- Real-time schedule information will be useful where transit is responsive to local needs. It would only by when sufficient service is provided relative to travel demand that agencies felt it would be feasible to present transit information on a widespread basis.

- The schedules and operations of carriers originating outside Orange County (e.g., LACMTA, Riverside Transit, Long Reach Transit) should be coordinated with OCTA operations, both at destinations within Orange County and at transfer points between lines. This also would require, if transit information is disseminated, that a similar level of relative information be available from the neighboring transit agencies.

4.2.4 - Interagency Traffic Management

The topic of interagency cooperation raised a great many issues. Most importantly it identified various needs of city staff as well as focusing on questions of leadership and means of improving interagency communication. Most comments in this regard came from local-level agencies.

The following identifies the most important elements identified by the agencies which would help promote efforts to improve traffic management through IVHS and which would strengthen interagency cooperation.

Local-Level Comments

A Information Needs

- There is much interest in the results of evaluations and monitoring of signal coordination projects including costs and benefits over short and long run. This should include not only green wave progressions but also area based timing strategies.
- City staff desire to be kept up to date on evaluation results of IVHS test and pilot programs (e.g., CMS, booths and kiosks, transit vehicles as probes, etc.)
- A valuable resource would be to develop and maintain a data base on IVHS hardware and software applications to include information on both purchase and maintenance costs, compatibility with other systems with notes on any constraints or limitations.

B. Staff Support

- Assistance to city staffs through technical support with regard to IVHS technologies including preparing grant applications.
- Technical assistance to city staffs which will promote coordination with Caltrans.
- Availability of portable changeable message signs to cities for special events and seasonal congestion problems.

In general, it was felt that the focus should be on cities where freeway construction is occurring, and also that have the staff and equipment to enact appropriate incident response strategies.

4.2.3 - Special Event Traffic Management

Orange County is home to many events during very heavy traffic. As was summarized in Exhibit 3.9 (Chapter 3), events range from regularly scheduled sporting events to annual events, with tourism and recreational travel accounting for seasonal surges in traffic flows, particularly on weekends. Largely, however, special event traffic tends to be concentrated in specific areas (e.g., Anaheim, Costa Mesa/Newport Beach area, approach routes to the Ocean), and not uniformly throughout the County.

Local-level and regional-level comments focused on both interagency traffic management as well as use of specific devices. These are discussed below:

Local-Level Comments

- Local agencies greatly prefer autonomy over selection of traffic signal controller manufacturers and systems, based on local needs. Nineteen cities currently use Multisonics VMS central equipment and Multisonics controllers. Agreed that exchange of traffic information at system level is essential but does not require a single county-wide standard for signal controllers.

- Use of fixed, permanent Changeable Message Signs (CMS) to direct traffic, such as those being utilized in Anaheim near Disneyland and the Convention Center, are most appropriate for locations with heavy special-event traffic through the year. For more seasonal or infrequent events, the use of portable CMS's may be more practical. A pool of portable CMS's for use by the different cities would be useful for special-event traffic management. At issue is who would fund, acquire and maintain the equipment.

- Increased use of Highway Advisory Radio (HAR) is restricting the availability of frequencies (e.g., Caltrans, Anaheim and Santa Ana have or will soon have HAR stations). There needs to be some control on allocation of the frequencies.

Transportation Management Associations
Media

The results of the interviews were assessed by type of respondent, and complete results developed for local and regional concerns, with additional input from neighboring and private sector entities.

Based on these discussions, a summary of each of the institutional issues is presented in the following sections, in terms of concerns, overall constraints and "wish lists" for consideration in the County-Wide IVHS architecture.

4.2.1 - Signal Pre-Emption for Emergency and Transit Vehicles

Many of the agencies interviewed commented that signal pre-emption is not a new idea or what they would consider IVHS technology. However, upon further discussion, they indicated a need for this issue to be addressed since traffic signal operations and equipment are an integral part of the overall traffic management system. Based on the interviews, the following summarizes the key areas of concern on the part of the agencies interviewed:

Local-Level Comments

- Cities as a whole do not support a county-wide signal preemption policy.
- Pre-emption can be disruptive to signal coordination

Regional-Level Comments

- The benefits and costs of signal pre-emption are not proven and, before it is used on a larger scale, the effects must be evaluated.

- Pre-emption should be evaluated on a regional or corridor basis and approached as a cooperative effort of all affected agencies/jurisdictions. The superstreets were suggested as ideal corridors for the use of pre-emption.

5 System Architecture and Recommended Elements

5. SYSTEM ARCHITECTURE AND RECOMMENDED ELEMENTS

5.1 INTRODUCTION

To carry out the required global transportation strategies, in light of the institutional and technical constraints identified in Chapters 2 through 4, this Chapter reviews a number of candidate solutions and system configurations in light of the overall system goals and objectives, and recommends an overall architecture for Countywide IVHS implementation.

5.2 DISCUSSION OF CONSTRAINTS

Chapter 4 provided an in-depth discussion of the implications of institutional issues in the development of the system architecture. The conclusions reached were:

- Local Traffic Management Autonomy is desired, with two-way communications added to allow coordinated operations.
- Limited staffing at local level means the IVHS architecture must provide the capability to develop strategies, monitor itself, and provide local agency staff with all the information needed to make a transportation operations decision readily.
- Automated sharing of traffic information between agencies is desired.
- IVHS Architecture should accommodate both large centralized system operations and smaller systems.
- Sharing of Central or Remote Operations may be desirable given limited staffing, provided the appropriate agreements and responsibilities are defined.
- These needs to be support at the regional level on advancements in technology as well as maintenance issues.

Other issues related to traveler information and user-orientation are as follows:

- Traveler information needs to be made readily available to the public. This information should include real-time in nature, and specifically include real-time transit location, including rail arrival times, estimated bus arrivals (where possible).

- The system should provide maximum flexibility for responding to events, including providing real-time information to travelers on a pre-trip and en-route basis, through either infrastructure-based (i.e., signage) or vehicle-oriented (e.g., in-vehicle devices, Highway Advisory Radio (HAR) broadcasts, other means) methods.

- To accomplish the above, the system will require a flexible communications network that provides agency-to-agency, agency-to-roadway, and vehicle-to-roadway communications capabilities at the minimum.

- The primary focus of the IVHS architecture needs to be on implementation of near-term elements, such that flexibility for expansion of the system to accommodate more advanced technologies can be implemented at an early stage. Although general guidelines can be developed for a 20-year horizon, it is difficult to ascertain the specific technologies that will be in place or when they will be developed.

5.3 MEASURES OF MERIT (MOMs)

MOMs represent quantities which can evaluate how well an IVHS architecture is working. Although Chapter 11 provides a more detailed evaluation of the recommended architecture, MOMs are shown here to provide the basis used for selecting various elements for inclusion into the IVHS architecture, particularly with regard to near-term programs. Those solutions with the greatest potential effectiveness represent major elements of the IVHS programs.

The following MOMs were selected based on their ability to be measured, and are presented below:

- Travel times/average speeds for representative origin destination pairs The most basic measure of movement of people and goods.

- Vehicle-Hours of Delay (Recurrent and Non-recurrent Congestion). Measurement of success in determining benefits, since costs can be associated with a vehicle-hour of delay. Delay here is defined as the additional time required for a single vehicle to travel due to recurrent stoppages (i.e., signal operations or capacity constraints) or due to an incident (non-recurrent congestion).

- System Life-Cvcle Costs. Include capital expenditures, engineering costs, installation, operation and maintenance.

- Accident Totals and Severity. Information on accidents is readily available. Estimated reductions based on evaluation of more widely-used elements such as ramp metering. Accident reductions due to in-vehicle sensors and other warning and correcting devices are not yet known due to their relatively narrow applications to date.

- Mode Split. Useful for evaluating policy decisions to increase use of public transit and High-Occupancy Vehicles (HOV). Difficult to predict since it assumes a certain level of flexibility for Orange County travelers in selecting alternate modes.

- Reduction in Emissions and Fuel Consumption. These measures are direct measures which impact quality of life considerations. They can be calculated as a function of reductions in vehicle-hours of delay as well as based on vehicle-miles traveled.

5.4 ARCHITECTURE EVALUATION

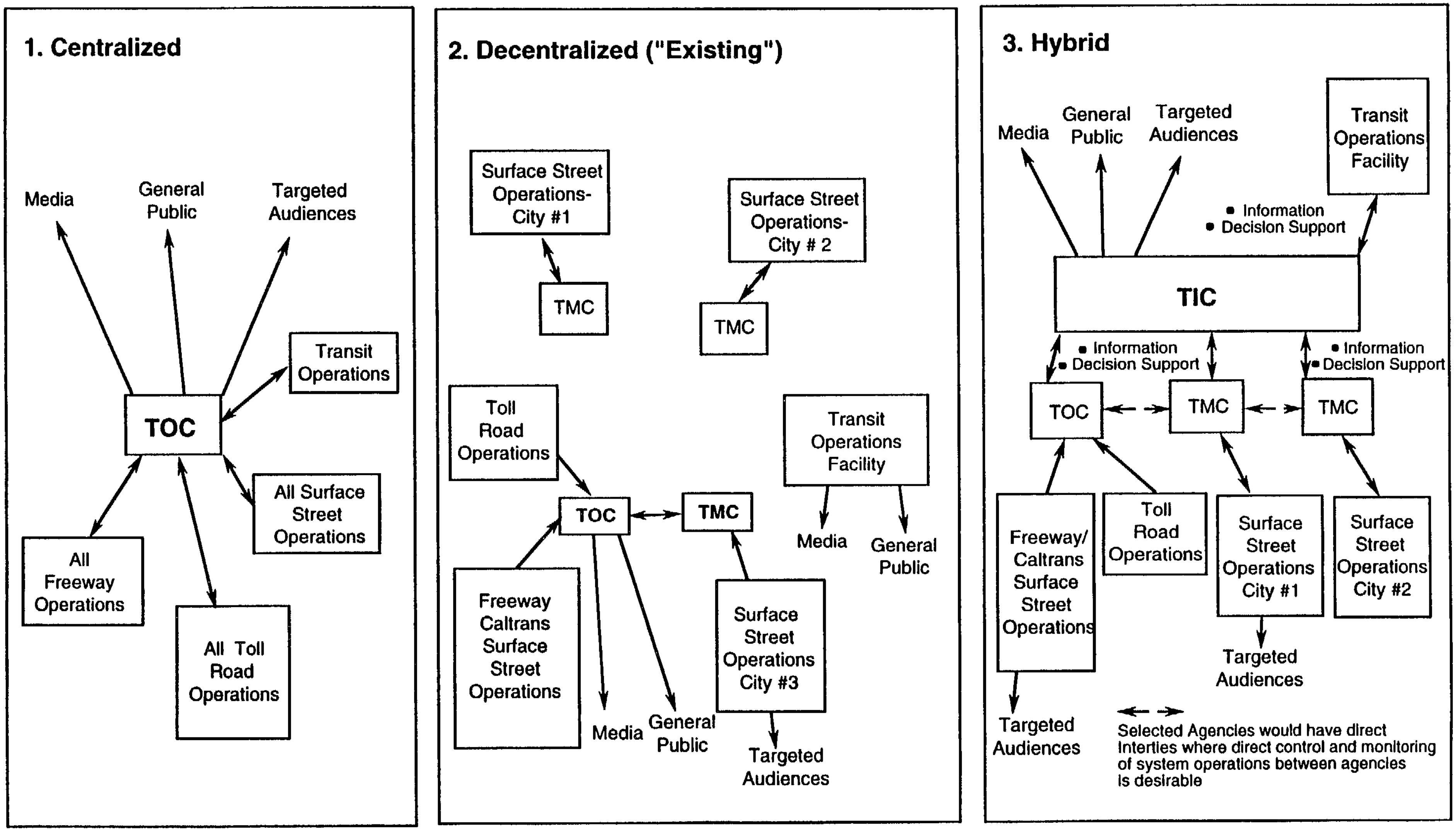
This section presents an evaluation of three alternative organizational structures for a Countywide IVHS architecture. The structures are evaluated in terms of specific criteria representative of the system goals and objectives as well as various system constraints. The recommended structure is then selected, and serves as the basis for organization of the system elements identified later in this Chapter.

5.4.1 - Alternative Structures

With the overall focus being driven by institutional issues and the need for multi-agency coordination and dissemination, an organization-based architecture was identified. Three candidates were selected for evaluation, and are illustrated in Exhibit 5.1.

Centralized architecture. This concept treats the county as a single multi-agency "Smart Corridor." There is a central Traffic Operations Center (TOC) that collects data, analyzes it, and controls all aspects, including signs, ramp meters, and surface street signals. It has the advantage of an economy of scale and the avoidance of delays or m&communications due to poor coordination.

Exhibit 5.1
Comparison of IVHS Organizational Structures



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Transit IVHS /comparison of IVHS Organ

Decentralized architecture. This is essentially the structure currently in place. Multiple agency or city Traffic Management Centers (TMCs) monitor and control roadways under their jurisdiction with a Traffic Operations Center (TOC) handling freeways. These centers are fairly autonomous, and communications between them are generally ad hoc using voice telephone, with a handful of agency interties for graphical traffic information. This has the advantage of flexibility, responsiveness to local needs, compatibility with organizational structures, and ease of transition.

Hybrid architecture. This structure has both the local Traffic Management Center (TMC), for local monitoring and control, a freeway Traffic Operations Center (TOC), and a county-wide multi-agency Traveler Information Center (TIC) for fusion of status data, major incident management, and control at a county level as appropriate. This is all tied together using automated data sharing. This has the advantage that information is shared globally without sacrificing the current local capabilities.

5.4.2 - Criteria for Comparison of Alternatives

To provide a more specific basis for comparing the three alternatives than possible through assessment of global goals, transportation objectives and strategies, criteria were selected which address functional and institutional requirements of the IVHS architecture as well as the goals.

The criteria are as follows, and relate to the global transportation strategies as illustrated in Exhibit 5.2:

- Interagency Relationships
- Dissemination to Public
- Information Sharing Between Agencies
- Smart Corridor Strategies
- Local Traffic Strategies
- Expandability/Flexibility

The criteria above provide an equitable, but by no means perfect means of summarizing the requirements of the strategies. It is apparent that some strategies (notably Congestion

Exhibit 5.2
CRITERIA FOR IVHS ARCHITECTURE STRUCTURE SELECTION BASED ON ORANGE COUNTY TRANSPORTATION STRATEGIES

Criteria / Strategy	Interagency Relationships	Dissemination to Public	Information Sharing Between Agencies	Smart Corridor Strategies	Local Traffic Strategies	Expendability / Flexibility
Manage Congestion - Recurrent						
- Non-Recurrent						
Reduce Traffic Turbulence						
Develop Decision Support & Response Mechanisms						
Manage Incidents - Detection/Verification						
- Response						
- Rapid Removal						
Provide TDM Tools						
Inform Travelers - Pre-Trip						
- En-Route						
Support Technologies to Enhance Safety						
Provide Full Accessibility for All Travelers						
Provide Info & Accessibility for All Agencies						
Develop Features to Enhance Maintainability & Cost Effectiveness						
Develop Facilities & Technologies to Reduce Emissions, Energy Use and Noise						

Management, Incident Management, and Traveler Information) are easier to satisfy through an IVHS architecture than other strategies.

The criteria above were thus utilized as the basis for an architecture trade-off comparison in the following section.

5.4.3 - Trade-Off Analysis

Trade-offs between the three architecture structures were evaluated and are presented in Exhibit 5.3. These are further summarized below:

- Centralized Architecture. This alternative has the advantage of enacting control and information strategies from one locale, which negates various institutional issues associated with traffic operations. However, it requires replacement and standardization of all local control equipment and the development of an extensive and costly countywide communications capability that is focused on a central Traffic Management Center (TMC) for freeway, surface street and transit operations and information. The system by nature is not as responsive to local traffic issues (due to its remote location and autonomy separate from the local agency). Hence, it is not institutionally acceptable. Furthermore, there would be no sharing of information, nor sharing of communications capabilities between more that one facility. Therefore, a major system or power failure or incident at the facility could potentially impact all Countywide transportation operations, due to lack of redundancy.

- Decentralized Architecture. As discussed above, this closely corresponds to existing operations in Orange County. The current situation protects the autonomy of local agencies in control and management of their traffic operations, with agreements between agencies based on joint project interests and as required due to specific construction projects or events. Such a structure by nature is not consistent throughout the County, and is heavily dependent on existing working relationships. The existing systems provide the potential for different information sources to be available, but do not provide a capability for a consistent source of travel information Countywide for dissemination to the traveler. Furthermore, the ability for joint agency responses to a real-time traffic condition is constrained by current system capabilities as well as the status of the agency relationships.

- Hybrid Architecture. The hybrid provides the capability for agencies to retain autonomy over current responsibilities, yet provides an infrastructure in which the systems can communicate appropriate traffic or transit information and decision support information. The heart of this architecture is a "Traveler Information Database" (TID) which is capable of receiving information from all freeways,

EXHIBIT 5.3
IVHS ARCHITECTURE
TRADE – OFF COMPARISON

Criteria	Centralized	Decentralized	Hybrid
Interagency Relationships	Not a Factor. All control centralized	Full agency autonomy. Agreements between agencies as desired.	Local control, but dedicated interagency communications and relationships
Dissemination to public	One source.	Many sources.	One source.
Information sharing between agencies	Not needed for central control.	Done as desired.	Automated, global availablity of traffic information, decision support
Smart Corridor Strategies	Implemented at single control site.	Implemented for agencies which have agreed working relationships (not consistent throughout County).	Implemented through dedicated cooperative effort between agencies.
Local traffic strategies	Difficult to implement (remote from local agency).	Easy to implement	Easy to implement
Expandability / Flexibility	One facility only. Not as responsive to local requirements.	Expansion of agency operations, may not benefit other agencies if not linked into network.	Expansion of local of regional capabilities enhances overallsystem, provides redundancy.

surface streets and transit facilities and outputting this information to the appropriate audiences through the appropriate information servers. An intermediate "decision support" function is utilized for agencies which are within Smart Corridors as identified in Chapter 3, such that coordinated traffic response strategies can be developed as necessary, and approved by the agencies for implementation. The architecture requires development of communication capabilities between all traffic control systems, the development of dedicatedinteragency relationships, plus the development of centralized traveler information and regional decision support capabilities.

5.5 IVHS INFRASTRUCTURE REQUIREMENTS - AGENCY AND CENTRAL

Within the hybrid structure just selected, the architecture can be further refined as it relates to the infrastructure. An infrastructure-based architecture calls for all elements to be in fixed locations or for mobile resources, such as Freeway Service Patrols, to utilize dedicated beats. An alternate approach is for the architecture to be supported by resource management that coordinates elements on-call, that is, based on specific needs. This IVHS Study, through evaluation of the technical and institutional issues and constraints, recommends an infrastructure-based architecture with the addition of selected mobile or on-call elements.

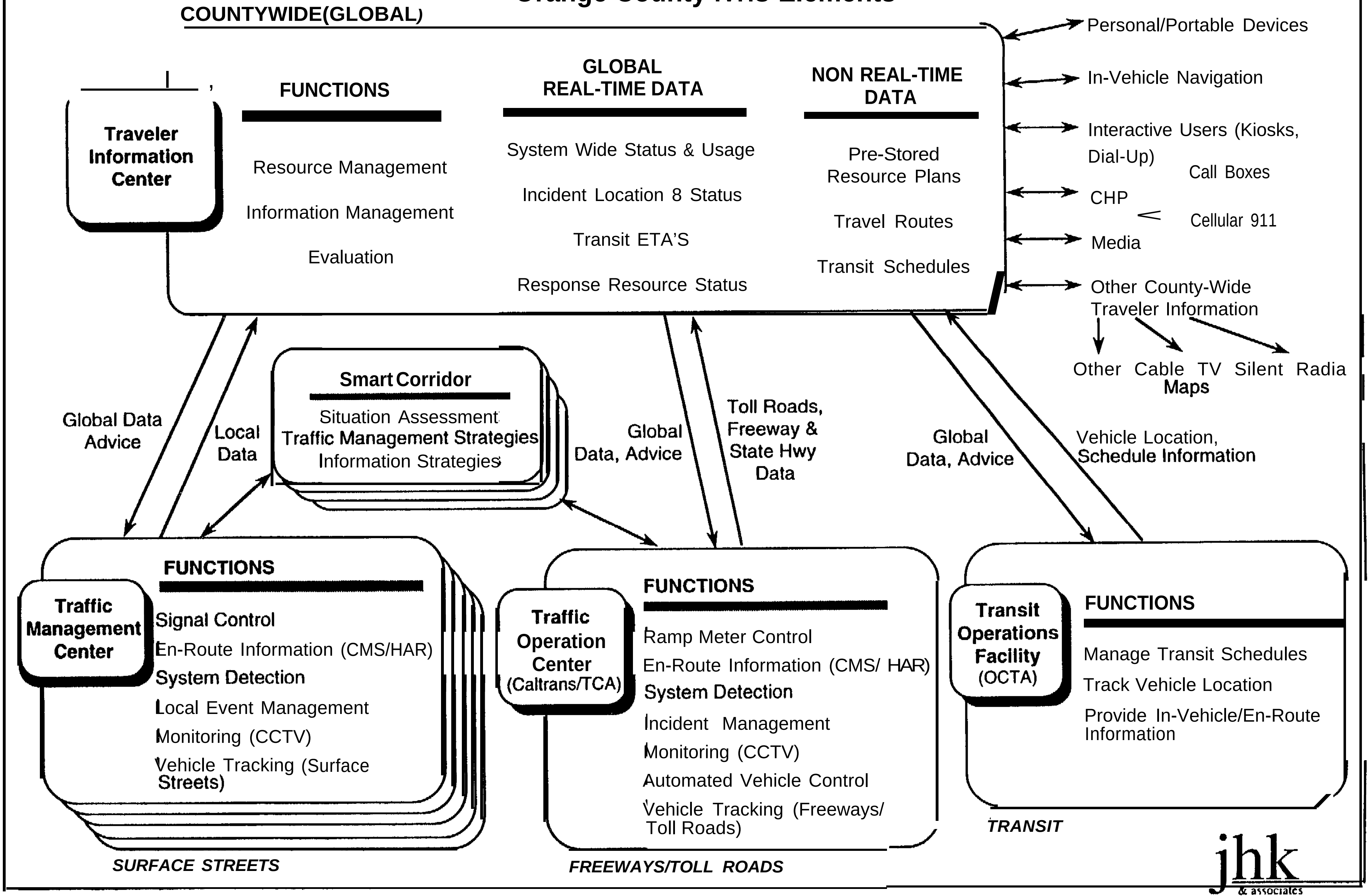
5.5.1 - Operations Centers

Exhibit 5.4 diagrams the overall hybrid architecture and system functions indigenous to the different Operations Centers. These are further described below in terms of operational characteristics and features:

Traveler Information Center (TIC) - Responsible for collection and dissemination of Countywide transportation information to the media, the public, and the in-vehicle user (except information presented via Changeable Message Signs [CMS] and Highway Advisory Radio [HAR]).

Caltrans Traffic Operations Center (TOC) - Responsible for traffic management on freeways and Toll Roads, and information dissemination through freeway CMS and HAR. Also manages traffic signals along state highways.

Exhibit 5.4
Overall Structure
Orange County IVHS Elements



Local Traffic Management Centers (single or multi-agency) - Responsible for traffic management on surface streets, and dissemination through surface street CMS and HAR.

Transit Operations Center - Responsible for management and tracking of transit service, providing in-vehicle information to buses, exporting schedule and real-time service information to TIC for dissemination to the public.

5.5.1.1 - Operations

The system centers around the collection, evaluation, and dissemination of data. The local TMCs and TOCs receive data from the detection devices or other resources within their jurisdiction (e.g., loop detectors, CCTV, police reports). This is used to monitor the traffic in the jurisdiction. It is also passed automatically to the TIC, where it is merged with data from throughout the County to provide the county-wide status. This status can then be called up by any TMC or by the Caltrans TOC using the means discussed later in this section. Furthermore, the use of Smart Corridor and related decision support (Expert System) elements will allow a faster detection of incidents or events to which the various centers should respond, and advise action. For example, a major accident on a freeway will cause one or more TMCs to be notified and asked to approve multi-jurisdictional diversion plans as proposed by the Expert System.

Such response plans, whether stored or dynamically developed, are a key element of this system. As discussed earlier, rapid response is a key strategy to reducing congestion and associated delay, safety and air pollution problems. Such plans by nature require substantial data and knowledge, therefore, it is recommended that the knowledge is codified in one or more Expert Systems that can assess the situation, find the appropriate response, and notify the various parties. The parties then accept or modify the plan as needed, and it is then implemented.

While the information is distributed and available to all, control resides with the TMCs and TOC. Such control is coordinated between the centers where appropriate, in particular for signal synchronization.

Institutional considerations may also permit one agency (e.g., Caltrans) to operate or monitor traffic operations for another agency if that agency has limited resources. Such an arrangement could be developed through the use of Memorandums of Understanding in order to identify and resolve potential liability issues as well as technical issues.

5.5.1.2 - Data Base

Countywide real-time transportation data would be maintained at the TIC in a common Traveler Information Database (TID). It is recommended that this be ultimately a geographic information system (GIS) as described in Chapter 6. This would provide a common reference for the large volume of position-specific data. It would allow multiple centers to exchange information, and also to correlate position-related information from various sources (e.g., inductive loops and motorist reports keyed to mile markers). It would also facilitate development of dynamic routing algorithms.

5.5.1.3 - Operator Displays and Decision Support

User-selectable map or text displays through a Graphical User Interface (GUI) will present information to a TMC or TOC workstation in a clear manner that is tailored to the user's needs. This will be supported by audible or visual alerts, as appropriate, to allow the Operators to monitor the system while carrying on their other tasks. For traffic engineers that spend much time in the field, alerts can be sent to a pager, and the displays will be available in their vehicles.

Expert Systems at the local and regional levels (TMC, TOC, possibly TIC) will codify standard traffic monitoring procedures in Smart Corridor areas and elsewhere in the County to form the alerts and messages. Specifically, the system will continuously look for anomalies in the detected data that might indicate a problem, recommend response strategies and submit the candidate actions to operations at Caltrans and local agency levels. The Knowledge-Based Expert System will include all baseline response policies and procedures, including recommended actions to be taken and the centers to be notified. Response Plan development would be dynamic in nature; where baseline response plans will be automatically tailored to real-time conditions and updated over the duration of the condition.

The Central TIC will contain analysis tools to provide a real-time assessment of overall system status. Also provided will be historical summaries and evaluations. Such ongoing assessments will be essential to cost-effective system expansion, since it will provide a basis for comparison of different strategies.

Any workstation in the system will be capable of selecting any combination of the following for map display. The user will have complete control over map feature selection. Such a display may also be "zoomed" into specific areas.

- Freeways and tollroads in Orange County and surrounding counties
- Smart Streets and Smart Corridor routes in Orange County
- Transit routes in Orange and Los Angeles Counties
- Other streets in Orange County

In addition, any of the following real-time data may be superimposed on the map display, with colors indicating status or level and user-selectable text notations. By prior agreement, and intertie with neighboring agencies, this may include areas outside Orange County.

- Traffic congestion (graphical data - freeway and surface street)
- Incidents and status
- Ongoing and planned diversions and construction
- Transit schedules
- Weather in Orange County and surrounding counties
- Special events and related status
- John Wayne Airport - parking, travel delays

The TMCs and TOC would have access through GUI workstations to all of the above, plus the following local real-time data.

- Equipment status
- Timing (local agency plus other jurisdictive)
- Current time (county-wide standard, using WWV time-base)
- Current messages on CMS, HAR
- Sensor data
- Alerts (congestion, incident, diversion, malfunction)
- CCTV (full motion or compressed depending on communication capacity)
- Expert System interface to gain access to response plans and traffic management functions below

Expert Systems will be included to perform at least the following.

- Incident detection, correlation, and confirmation
- Response plans

- Alerts to agency staff not at TMC or TOC
- Flow balancing
- Multimodal route planning
- Information dissemination

5.5.1.4 - Communications (Center-to-Center)

Communications will be done using the lowest cost medium for the location and the application needs. This should be determined on a case-by-case basis depending on existing infrastructure, geographic location, and available resources. The major requirement is interoperability. The system will provide voice and digital data between the TMCs and TOC through the TIC and between adjacent or otherwise coordinating TMCs.

5.5.1.5 - Communications (Center-to-Roadway)

There will be two-way, full-duplex communications between the roadway and the responsible center. The responding system will, as appropriate, formulate strategies or messages and send them to the right agencies or equipment, based on previously agreed policies and procedures.

5.5.1.6 - Traffic Control and Multi-Agency Coordination (Center-to-Roadway)

Signals and ramp meters will be controlled from TMCs and TOCs based on adaptive timing and predetermined rules. For example, ramp metering will be responsive to flow on the freeway and demand on the ramp, but will also be remotely modifiable from the center to quickly restrict flow upstream from an incident and increase flow downstream from it, or to relieve a backup onto surface streets. The controllers do not need to be the same, but must be able to coordinate with each other, through central-tocentral communications links as well as through a common time base such as WWV. Smart Corridor-based Expert Systems are to have the capability of integrating specific freeway and arterial elements and producing specific response plans.

5.6 FREEWAY ELEMENTS

The architecture elements used in the freeway portion of the architecture are illustrated in Exhibit 5.5, and the elements' function and selection criteria are shown in Exhibit 5.6. A number of these are currently being implemented under the Caltrans TOS Master Plan, and are described as such In addition to these elements, others are assumed to be in place as a result of ongoing congestion management programs or initiatives pursued by the traveler. These include Motorist Aid/call boxes along freeways and rural routes and Cellular Phone-based ("Cellular 911") incident reporting by motorists. Both of these elements are existing. Though they are not specifically identified within the architectures, their effects will be enhanced by some of the communications elements identified below. These include better communication and control processors at the centers and direct computer-to-computer interties with local police and CHP computer-aided dispatch (CAD), fire departments, ambulance services, and hazardous material teams.

5.6.1 - Roadway Detection

To detect traffic flows (volumes, occupancy, speeds, potential incidents), the Caltrans TOS Master Plan recommends the use of electronic loop detection embedded in the pavement for all freeways and toll roads. The loops are connected to roadside Type 170 controllers for processing and transmitting data to the TOC's Central Computer. Loop detection is currently located on approximately 110 miles of Caltrans freeway. Based on studies done by JHK & Associates for Caltrans District 4 regarding spacing of freeway detection, this IVHS Study recommends a maximum spacing of l/2 mile between surveillance stations. This allows system incident detection algorithms to perform without excessive "false alarms" as well as providing a more precise representation of where congestion is occurring along the freeway. Spacing of less than l/2 mile is common when ramps are located more closely together. Mainline surveillance stations are required in conjunction with ramp metering to allow performance of local traffic-responsive metering as well as more extensive corridor-wide strategies.

Future technologies in detection should be considered wherever they have the potential for reduced cost, greater reliability, and improved accuracy. Some of these newer technologies

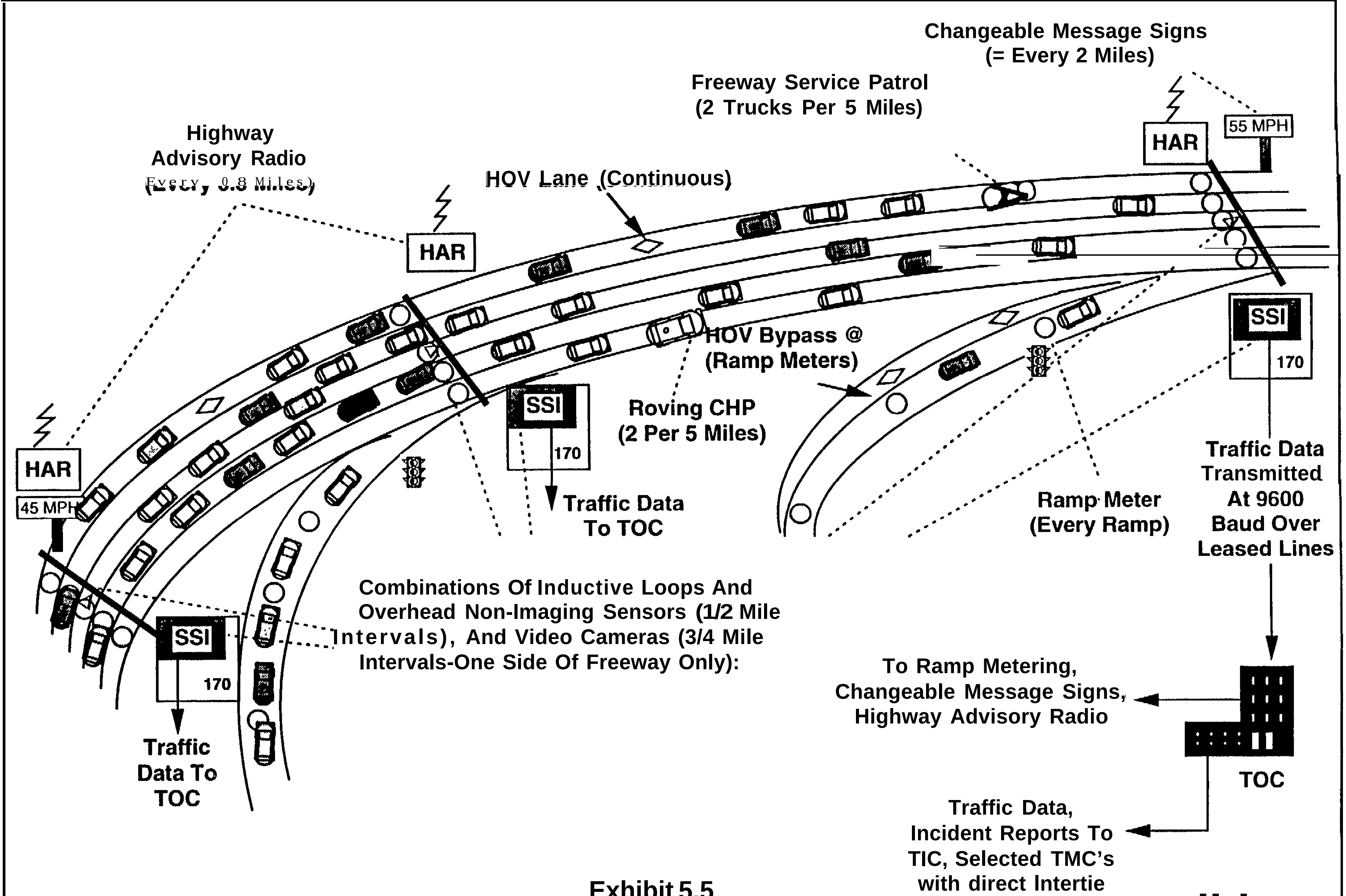


Exhibit 5.5
Near-Term Freeway Architectures (4 lanes in each direction)

jhk & associates

EXHIBIT 5.6 Orange County IVHS Architecture

NEAR-TERM ELEMENTS (FREEWAY)	Function	Near-Term Location Criteria*
Accident Investigation Sites	Remove Incidents from view of traffic	15 ml spacing
Traffic Operations Center (TOC)	Manage Freeway traffic operations	.
Changeable Message Signs (CMS)	Provide traveler Information/route guidance	2 m I ahead of m ajor fwy-fwy interchanges
Closed-Circuit Television (CCTV)	Incident Detection/Confirmation, Congestion Management	0.75 ml spacing
Call Boxes	Reduce Incident Detection time	025 ml spacing each diection
Freeway Service Patrol (Roving tow trucks w/AVL mobile data Terminals)	Reduce Incident detection, response, clearance times	2 trucks/5 ml beat
Highway Advisory Radio (HAR)--Low Power	Provide traveler Information--roadway-specific	1/4 ml spacing in Smart Corrldors
Ramp Metering	Increase speed & safety on fwy/divert traffic	256 metered ramps
Roadway Detection (loops, radar, microwave, wide area)	Incident/congestion detection, data collection	050 ml spacing
Video Image Processing Systems (VIPS) or VIDS	Congestion detection/Fwy Incident detection/conformation	25% of CCTV locations
Electronic Toll & Traffic Management	Reduce recurring congestion on toll roads	On all toll facilities

* Location Criteria as per the Following:

Smart Corridor Statewide Study, 1990
District 4 Traffic Operations System, Operational Procedure8 and Strategies Conceptual Design Report, 1992
Proposed District 12 Traffic Operations System Master Plan. 1992
Orange County TOC Study, 1991

include microwave, infrared, acoustic detection, as well as video image processing.

The Near-Term IVHS Architecture utilizes 1.58 freeway surveillance stations (non-tamp metering), along with 122 stations associated with ramp meters.

5.6.2 - Closed-Circuit Television (CCTV)

The TOS Master Plan calls for 75 CCTV cameras on the freeway system, providing l/2 mile coverage in each direction along a freeway, particularly including freeway-to-freeway interchanges and critical intermediate interchanges. CCTV provides the capability to confirm congestion or incidents in advance of CHP or other mobile response resources, thus providing for a more rapid dispatch of FSP or emergency vehicles, as well as more rapid implementation of traffic management strategies.

Currently 5 CCTV cameras have been installed, with 26 cameras programmed for future installation and 44 proposed cameras which have not been funded The District 4 study has recommended spacings of 3/4 mile between cameras, so as to allow for complete coverage of the system, including some overlap. If this design is followed in District 12, a total of 183 cameras would be required to provide this full coverage. Such coverage can be afforded through use of some lower-cost camera technologies, including digitized "slow-scan" video, which provides a lower level of functionality in less critical areas, yet provides the ability to confirm an incident location and the status of traffic.

The proposed Near-Term IVHS Architecture utilizes 75 CCTV cameras for freeways, with 183 cameras for the Mid-Term system.

5.6.3 - Accident Investigation Sites (AIS)

While not an IVHS element per se, AIS has the potential to support IVHS-related strategies to reduce non-recurrent congestion by providing a facility out of the sight line of the freeway mainline, typically off a freeway ramp and shaded by shrubs or trees. The AIS allows an accident to be towed directly from the freeway mainline to this off-site facility. Typical requirements for an AIS include on-off access to the freeway (this is typically achieved by locating the AIS off a freeway off-ramp). Also necessary in this regard is adequate right-of-way for the AIS A number of demonstration AIS locations are being developed as part of the Santa Monica Smart Corridor project in a cooperative effort between Caltrans and CHP.

5.6.4 - Changeable Message Sign (CMS)

The CMS is the most visible method of providing real-time traffic advisory and route guidance information on the roadway. The TOS Master Plan proposes CMS on freeway approaches in advance of one local interchange before a freeway-@freeway connection. This will allow the possibility for diversion strategies involving major surface streets if appropriate. The Project Team recommends the use of full-matrix CMS for freeway use. Full-matrix CMSs provide maximum flexibility in letter size and accommodates the use of standard symbology when necessary to convey specific messages. Other CMS locations can be in areas where weather-related or event-related congestion occurs with some regularity. Caltrans has proposed a total of 42 signs, with 6 currently operational, 24 programmed, and 12 proposed but not funded.

The proposed Near-Term IVHS Architecture includes a total of 42 freeway CMS.

5.6.5 - Highway Advisory Radio (HAR)

Caltrans currently operates two lo-watt HAR stations, with one additional lo-watt station currently operated by the City of Anaheim. HAR can provide important real-time traffic information in more detail than possibly utilizing CMS alone. Use of Mobile HAR is being proposed by the TOS Master Plan, and six more HAR stations are currently being proposed. However, HAR, in combination with appropriate automation and voice digitization, can provide more specific and relevant real-time information by being oriented in linear low-power broadcast zones along freeways. Such a scheme is being implemented for the Santa Monica Freeway in Los Angeles in conjunction with the first Smart Corridor project. The most recent low-power technologies utilize 0.1 watt of power for each transmitter with an approximate l/2 mile transmission radius. Overlap between zones and resultant hetrodyning (interference) is mitigated through the use of synchronization techniques.

The Near-Term IVHS Architecture thus departs from the Caltrans TOS Master Plan in recommending low-power HAR transmitters located along Smart Corridor segments. Spacings of l/4 mile are to be considered based on initial test bed results in Los Angeles. In addition, the longer term architectures would include a number of newer broadcast technologies, including the use of Radio Data Systems and Traffic Message Channels which provide both text and audio messages.

5.6.6 - Freeway Ramp Metering

Ramp Metering, the primary means of controlling congestion at on-ramp/mainline junctions, is used at 231 on-ramps, with 25 additional meters programmed for installation. The Near-Term Architecture assumes a total of 256 metered ramps, with 94 of these currently having an HOV bypass lane.

5.6.7 - Video Image Processors (VIPS)

VIPS are recommended for high priority incident management corridors and at major interchanges and locations near major trip generators. VIPS allows the use of video imaging and a user-definable graphical overlay that is developed using dedicated PC software. The full range of traffic data (e.g., count, speed, occupancy) can be detected even if the Operator is monitoring another site, and algorithms can be utilized which can detect the presence of a potential incident. Upon an alarm or warning, the Operator can actively monitor the video image to verify incident presence.

The IVHS Advanced Testbed Project sponsored by the Federal Highway Administration, Caltrans, UCI, and the Cities of Anaheim and Irvine will install 21 VIPS locations on the freeway system. With lower costs and improvements in the technology becomes more common, it is possible that VIPS will be possible for all CCTV cameras in the network. Thus, although the Near-Term Architecture includes only 21 VIPS locations on freeways, it is proposed that the Mid-Term architecture provide 183 VIPS locations (same as the number of future CCTV locations).

5.6.8 - Freeway Service Patrol (FSP)

OCTA, Caltrans, and CHP in a cooperative effort have implemented FSP service along approximately 45 centerline miles of freeway in Orange County using 15 trucks. FSP is designed to reduce non-recurent congestion through rapid removal of incidents from the freeway. FSP has the capability of removing stalls, performing minor repairs, or providing fuel as necessary to allow stalled vehicles to move out under their own power. For accidents, FSP can assist in accelerating the detection and confirmation process, thus allowing resources such as CHP and emergency vehicles to reach the site more quickly. (FSP, however, does not remove vehicles involved in accidents from the traveled way. Contract tow vehicles remove the vehicles involved in accidents.)

The Near-Term Architecture assumes an FSP expansion to the full frequency network as currently programmed. While FSP itself does not represent an IVHS improvement, the use of strategies including Advanced Vehicle Location (AVL) and automated mobile data terminals (MDT's) contribute to the effectiveness of FSP as a tool, and critically, provide a source of information for the system. Therefore, the use of FSP has been incorporated into the IVHS Architecture.

5.6.9 -High Occupancy Vehicle (HOW Lanes

Currently, HOV lanes have been implemented on a segment of I-5 (Route 55 to I-405), as well as on I-405, Route 55, and Route 57, and are under construction along I-5 south of Route 22. The Caltrans TOS Master Plan projects HOV lanes on all freeways except Route 22. HOV is a major element in Transportation Demand Management, in that it encourages the use of carpooling and public transit to reduce congestion. While HOV lanes in themselves are not IVHS elements (and thus will not be evaluated as part of the IVHS architecture per se), their presence provides an operational enhancement to the infrastructure which can increase the effectiveness of IVHS elements, particularly as they can influence mode selection and reduce delay through a reduction of single-occupancy vehicles.

5.6.10 - Electronic Toll and Traffic Management (ETTM)

ETTM systems reduce recurring congestion on toll facilities by allowing vehicles with special bar code decals or other Automatic Vehicle Identification (AVI) tags to travel through toll collection areas at close to normal travel speeds. Bar-code readers at the side of the road, are connected to a centralized monitoring and toll management system. Recording of these vehicles' travel on the toll road allows for automated billing of tolls. Non-tagged vehicles would be diverted to normal toll collection facilities. The newest technology tags provide for two-way vehicle-roadside communication This permits the transmission of vehicle identification data that can be used to calculate link travel times and thus serve as an input to the traffic data collection process. The Near Term Architecture incorporates the proposed use of ETTM as an integral element of the TCA's Toll Road system.

5.6.11 - Vehicle-Roadside Communications

As discussed above, the use of two-way vehicle-roadside communications supports real-time traffic data collection efforts, but also allows for transmission of information to suitably-equipped vehicles. The use of AVI tags allows recording of vehicle identification as they pass reader/scanner locations. By matching codes between scanner sites, link travel time and link information can be developed as well as improved origin-destination information for use by planners.

Operation and transmission of information to and from vehicles requires a high-capacity communications link with minimal maintenance requirements. The vehicle-roadside links can be accomplished using relatively simple technologies, including cellular phone, radio, and detector-based RF transmission. Either fiber optics or microwave could be used for these purposes.

Vehicle-roadside communications is a technology in its infancy for real-time applications. Though a simple version of vehicle-roadside communications can be developed for AVI purposes, JHK feels more research and development work is necessary before implementation. Therefore, the Near-Term Architecture includes a number of initial AVI and vehicle-roadside communications strategies. The use of one-mile spacings for AVI readers and roadside communications devices is selected based on the discussions presented in Chapter 6.

5.6.12 - Backbone Communications Network

The Caltrans TOS Master Plan has identified a number of fiber optics trunk facilities to be installed along the freeway system. Because of the cost of fiber optics installation in new conduits (reduced if done as part of other reconstruction work), it is important that these facilities be used to their maximum potential. The Near-Term Architecture uses the fiber trunk facilities as feeders to a central&d Traveler Information Center from local TMCs as well as the Caltrans TOC.

Alternatives to utilizing the fiber network include the use of owned or leased telephone facilities or microwave facilities. Phone-type facilities (including use of owned twisted-pair cable) for video transmission require some form of digital compression techniques, including coder-decoder (CODEC) devices and modems. Other unbounded techniques such as microwave and spread spectrum radio may also be utilized to reach locations remote from fiber trunk facilities.

A combination of different communication technologies could be used system-wide depending on local and agency requirements and funding; however, fiber will be utilized as the baseline trunk medium for development of costs and benefits, so as to produce a more conservative assessment of the IVHS architecture benefits and costs.

5.6.13 - Summary of Benefits: for Freeway Elements

The elements listed above can be divided into classes that support better management of recurring congestion due to capacity shortfall and of non-recurring congestion due to incidents as shown in Exhibit 5.7.

A summary of the estimated quantitative benefits assigned to the freeway congestion management elements is shown in Exhibit 5.8. It must be mentioned that benefit estimates are intended to give only a rough order of magnitude indication of effectiveness. There are many reasons for this, including the newness of many technologies, local differences in

EXHIBIT 5.7

ARCHITECTURE ELEMENTS THAT AFFECT RECURRING AND NON-RECURRING CONGESTION

Element	Recurring Congestion Reduction	Non-Recurring Congestion Reduction
Vehicle detection using inductive loops or other technologies	x	x
Incident detection with Video image processors		x
Incident detection with CCTV		x
HAR	x	x
CMS	x	x
Ramp metering	x	
Smart corridor strategies (see System Elements)	x	x
Freeway Service Patrol (FSP)		x
ETTM	x	x
Roadside-to-traveler communications	x	x
Roadside-to-center communications	x	x
Center-to-operations center communications (Interties)	x	x
Direct computer-to-computer intertie with local police, CHP, fire department, and hazmat teams		x

EXHIBIT 5.8

QUANTITATIVE BENEFITS ASSIGNED TO FREEWAY ARCHITECTURE ELEMENTS

Element	Effect on Congestion (see key)	Configuration	Reduction in Vehicle Hours of Congestion in Percent
Inductive loops	1	1/2 mile spacing Wt. 1)	26 (non-recurrent)
	1	1/4 mile spacing (Alt. 2)	39 (non-recurrent)
Video image processors	3	At high priority incident management corridors	20 (non-recurrent)
CCTV	3	At medium priority incident management corridors	10 (non-recurrent)
Low power highway advisory radio	5, 6	1 mile spacing	10 (non-recurrent)
Changeable message signs	5,6	1/2 mile before decision points	17 (non-recurrent)
Vehicle detection	1	At all interchanges and ramps	N/A
Ramp metering	6	On congested corridors	20 (recurrent congestion)
Smart corridors (see System Manager)	5, 6	Along freeways identified in Statewide Study as Smart Corridors	13 (recurrent congestion)
Freeway Service Patrol with AVL and mobile data terminals	4	1 truck per 5 miles each way on highly congested freeway sections	3 0 (non-recurrent)
ETTM	1, 6	on toll roads	Not available
Roadside-to-traveler communications	5.6	All vehicles via radios and at major public areas via displays	11 (recurrent Congestion) (based on Smart Corridor forecast)
	4	centers	Included in computer-to-computer intertie benefit
Direct computer-to-computer interties	4	Local police. CHP, fire departments, ambulance services, hazmat teams	8 (non-recurrent)

Key: <u>Incident Management Functions</u>

1. Reduction in incident detection time
2. Reduction in incident identification time
3. Reduction in incident detection and identification times
4. Reduction in incident detection, identification. and asset arrival times
5. Diversion of traffic in response to an incident

<u>Recurring Congestion Functions</u>

6. Management of reaming congestion

Sources:

"Operational Procedures and Strategies Conceptual Design Report Draft," JHK & Associates, May 1992

"Orange County TOC Study," JHK & Associates, August, 1991 implementations and traffic patterns, and interactions of the various system components. The primary benefit assigned to each element is its ability to reduce vehicle hours of congestion. This measure of effectiveness allows cost savings attributable to reduced delay to be compared with costs associated with installing and maintaining the architecture. (See Chapter 11, "Expected IVHS Benefits".)

Included in this assessment is a summary of the benefits of system elements, including provision of control centers and interagency communications. While these elements may in fact be invisible to the traveler, it is these elements (discussed under System Elements) that will allow the other elements (both freeway and surface streets) to function more efficiently.

5.7 SURFACE STREET ELEMENTS

The architecture elements used in the candidate Orange County surface street arterial architecture and the element's function and selection criteria are shown in Exhibit 5.9.

5.7.1 - Adaptive Control

Adaptive signal control is an important element of any IVHS architecture as it provides a means to reduce freeway congestion and make more efficient use of existing city transportation assets. The controlled streets currently use time-of-day plans to synchronize signals and speed traffic flow. In the future, real-time traffic responsive and adaptive algorithms may be used to provide greater benefits. Several demonstration projects have been implemented in Southern California to measure the benefits of this element. One of these is the Katella Avenue Project which synchronizes traffic signals previously controlled by six cities, the county, and Caltrans. ATSAC, in Los Angeles, has measured the benefit of synchronized signals as 13% with respect to reducing overall travel time. In Oxnard, a signal system utilizing the British SCOOT system has been implemented. Scoot utilizes system detectors along the coordinated roadway both approaching and departing the intersection.

Benefits from three field-based evaluations of optimized signal timing were reported by the GAO in a 1991 document, "Smart Highways, An Assessment of Their Potential to Improve Travel", GAO/PEMD-91-18, May 1991. Their findings included:

EXHIBIT 5.9

ORANGE COUNTY IVHS ARCHITECTURE

Near-Term Elements (Surface Streets)	Function	Near-Term Location Criteria*
Traffic Management Centers (Local Level)	Manage Surface Street Operations	Up to 9 In County (Ana, IN, Sta. Ana, 6 others)
Changeable Message Signs (CMS)	Provide travel Info for parking, alt. routes, closures (seasonal)	On Super Streets, SC roadways In advance of freeway
'Trailblazer' CMS for pre-planned alernate routes	Provide positive guidance for alternative routes	Along Smart Corridor roadways
Closed-Circuti Television (CCTV)	Congestion Mgmt, Incident Confirmation @ hlgh volume loations	25% of signalized Intersections
Highway Advisory Radio (HAR) – Low Power	Provide traveler information -- roadway-specific	1 mile Intervals along SC roadways
Mutual Aid Agreements (emergency services)	Provides Interagency agreement on emergency response routes	(Global)
Roadway Detection (loops, radar, microwave, wide area)	Input to real-time signal control, data collection	1/2 ml. Intervals & 300' in advance of major Intersections
Signal Pre-empdon for Emergency Vehicles	Provides dedicated emergency response strategy	Assumed 66% of county roadways
Signal Synchronization (TOD/DOW-based)	Increase capacity and flow speed on surface streets	89% of county roadways
Signal Synchronization (adaptive/traffic-responsive)	Increase surface street flow under non-recurrent conditions	Along Super Streets, SC, other key roads
Video Image Processing Systems (VIPS) or VIDS	Congestion detection/Fwy Incident detection/conformation	25% of CCTV locations

* Location Criteria as per me following:

Smart Corridor Statewlde Study, 1999
District 4 Traffic Operations System, Operational Procedures and Strategies Conceptual Design Report, 1992
Proposed District 12 Traftic Operations System Master Plan, 1992
Orange County TOC Study, 1991

1. 1982 FHWA Study (11 cities). For each controlled intersection the results were an average 8.5% improvement in travel time, 15,000 vehicle-hours of delay saved, and 10,000 gallons of fuel saved over a one-year period.

2. 1986 Fuel-Efficient Traffic Signal Management (FETSIM) covering 61 cities and 1 county in California. As a result of improved traffic signal timing, travel time was reduced by 7%, delays were reduced by 15%, and fuel consumption was reduced by 8.6%.

3. 1987 Los Angeles Department of Transportation (LADOT) ATSAC (Automated Traffic Surveillance and Control) study: The implementation of an extensive loop system at approximately 115 intersections in the Coliseum area, as well as video cameras for surveillance resulted in overall travel time reduced by 13%, intersection delay reduced by 20%, fuel consumption reduced by 12.5%, stops reduced by 35%, and air emissions reduced by 10%.

Adaptively controlled surface streets acting as freeway alternatives (i.e., Smart Corridor) are to be linked to the freeway architecture in order for the traffic signals to handle any excess traffic which may result in major congestion, especially during incidents. The HAR and CMS elements of the freeway architecture are used to inform drivers of acceptable alternate routes.

5.7.2 - Detection Elements

Inductive loops will serve as a primary near-term element for system-controlled intersections and for isolated intersection control. They are reliable if properly installed in stable roadbeds, and road and utility repairs are controlled to prevent inadvertent cutting of loops or connector cables. As in the freeway architecture, however, attention should be paid to the development and evolution of newer technology detectors. Since a typical two-lane street with a left turn pocket uses ten six-foot by six-foot inductive loop detectors in each direction, the cost of installing and maintaining this many loops becomes comparable with that of purchasing a Video image processor (VIP).

CCTV is recommended in near-term architectures to survey traffic and identify incidents at high priority intersections and near recreational, educational, and other high traffic volume facilities such as business parks, shopping centers, airports, sports complexes, theme parks, beaches, theaters, etc. Cameras purchased for these areas can be used with future VIP processors that can be added for medium-term and long-term architecture implementation, assuming the capability to switch from the pan-zoom mode of CCTV to the very precisely fixed VIP mode is developed. These VIPs can be tied into real-time traffic adaptive signal control systems to provide the traffic data required by the algorithms. CCTV can also be used for verification of defective traffic control equipment in the field.

VIPs are recommended as demonstration projects. These sites can be selected from those at major interchanges and highly trafficked intersections. New technology VIPs process the video imagery at roadside to produce the required traffic data (count, volume, speed, occupancy, incident detection) that can be transmitted to a central location on low bandwidth communications lines. If an incident or other traffic abnormality is detected by the VIP, an alarm can be sounded at the operations center and the Operator can request the real-time video transmission of imagery from the scene. If the video is not required, the Operator reduces his system's operation cost because high bandwidth lines are not unnecessarily tied up. As compared to CCTVs, the VIP does not require the large bandwidth communications line to the operations center at all times and, for a nominal additional cost, provides much more information than the CCTV.

Vehicle detection is recommended at shopping mall exits and large parking garages and lots that empty onto major surface streets. In addition to metering vehicles onto the streets, the detection information can be used for historical data collection and to plan road improvements for the future. The detectors recommended for near-term installation are inductive loops because of the reasons cited above. However, the evolution of the new detector technologies should be monitored for the added data and accuracy they can provide.

Call Boxes are currently used on rural routes in the County, including Ortega Highway (Route 74), Laguna Canyon Road (Route 133), and Santiago Canyon Road

5.7.3 - Advisory and Control Elements

Low power highway advisory radio (HAR) at recreational and other high traffic volume facilities is recommended for near-term use based on conclusions reached in the Operational Procedures and Strategies Conceptual Design Report. The low power radio allows messages to be restricted to smaller areas, and hence deliver more specific and localized information, than if present day higher power HARs are used. As roadside-to-vehicle communications continue to develop, other communications elements may be introduced in the medium and long term architectures.

Changeable message signs (CMS) provide information to travelers about recurring and non-recurring congestion that may lie ahead In the arterial architecture, they are recommended for fixed installations near recreational and other high traffic volume facilities. Portable CMS are recommended for use in construction zones to enhance safety and manage congestion by warning drivers of lane closures and other diversions, and at incident sites for similar reasons, or at seasonally or occasionally congested areas, such as beaches or special events. Trailblazer signs can be installed at critical points along a corridor to inform drivers of the recommended alternate route and the shortest path back to an uncongested freeway segment

The cost of elements such as CMS may be prohibitive given the relative frequency of usage by local agencies. It is proposed that a fleet of 80 portable CMS devices be made available for use by any agency for seasonal or unique events, traffic flow problems or for incidents which cause major traffic impacts. This would augment trailblazer CMS's along surface streets plus a number of corridor-based full-size CMS's in advance of freeways.

5.7.4 - Emergency Signal Preemption

Emergency preemption is an area that was recommended for further study by the Addendum to Task 1, "Pre-emption for Safety and Transit." This Working Paper recommends 1) a study of specific areas where multi-agency pre-emption strategies would enhance the emergency services system, 2) modeling of identified corridors to estimate the traffic impacts of pre-emption relative to the benefits, and 3) a test bed project of pre-emption on a multi-agency corridor.

Two corridors are identified here for consideration for implementation of the emergency signal preemption test bed. These corridors, Moulton Parkway (southern section) and Crown Valley Parkway, may prove well suited for preliminary testing and implementation of emergency signal preemption as both are designated Smart Streets, they each comprise multi-agency areas, the County provides fire department services to all jurisdictions in the areas, and the majority (all but the City of Mission Viejo) receive traffic signal operational support from the County.

5.7.5 - Backbone Communications

The Backbone Communications concepts discussed for freeways are relevant on the surface streets as well. The selection of fiber-optic or leased lines will be made based on specific system requirements. Wireless media can be considered for point-to-point communications in hard to access locations and for intra-center communications. These links may also be used to transmit traffic data from intersections to a field-hub, where the data are then routed over dedicated or leased lines to the TMC. In quantity, this medium provides low-cost alternatives to dedicated lines and leased lines, and allows for ownership of the transmission media.

Likewise, the use of vehicle-roadway links as discussed in the freeway elements apply to surface streets as well. Technologies being tested include RF beacons and infrared seamer devices. As with freeways, one-mile spacings for vehicle-roadway communication devices are used.

5.8 GLOBAL SYSTEM ELEMENTS

The Near-Term IVHS Architecture unifies the freeway and surface street elements into a cohesive system through the use of key system-wide elements (listed in Exhibit 5.10 based on function and location criteria. The elements will be oriented toward the global strategies presented in Chapter 2. To accomplish the strategies, the global elements must provide the following capabilities:

- Pre-Trip and En-Route Information Dissemination.
- Real-Time Traffic Management through coordinated decision support and response strategies.
- Support global accessibility for users and full coordination and data exchange between agencies.

Global elements in the near-term will include the following:

EXHIBIT 5.10

ORANGE COUNTY IVHS ARCHITECTURE

Near-Term Elements (System)	Function	Near-Term Location Criteria*
Expert Systems	Provides knowledge for selection of response	1 workstation / 2 Smart Corridors
Integrated freeway – arterial control (Smart Corridors)	Manage congestion/routing through selection of response plans	(See Above)
Mobile command systems (civil defense)	Manage evacuation routing	Up to 4 available
Mobile Highway Advisory Radio (HAR)	Provide traveler information – – roadway & time specific	Up to 8 available
AVL/GPS system for congestion/speed monitoring	Provide real – time data source for monitoring	(Global)
Origin – Destination data through AVI/AVL	Provides information for guidance and planning purposes	(Global)
Portable CCTV for image transmission from incident site	Incident confirmation/management/congestion management	Up to 4 available
Roadway-Central Communications -- Point-to-point	Transmit traffic data/video	0.5 ml spacing (same as detectors)
Vehicle-Roadside Communications	Transmit traffic data/vehicle location/Information	0.25 mi spacing (Call Box on freeways)
Graphical Traffic Information on Cable TV	Transmit traffic data In graphical map form	(Global)
Automatic Vehicle Identification (AVI)	Provides identification, locatlon, other pertinent info from vehicle	(Qlobal)
Cellular 911	Assists In detection/confirmation of incidents	(Global)
Traveler Information Center (OCTA)	Coordinates all data for dissemination throughout County	1
Dial-up Telephone Services	Provide specific traffic Info through normal phone services	(Either Private or HAT – – see below)
High -Speed Data and Video Comm Interties	Data exchange for interjurisdictional traffic mgmt/Information	1 per TMC/TOC to TIC, plus 3 TMC to TOC direct
Microprocessor Field Controllers	Intelligent control traffic mgmt elements to reduce congestion	0.5 ml spacing
Evacuation Routes and Response Plans	Reduce congestion through carefully developed responses	(Global)
Geographic Information System/Database	Graphical data base coordinating data from all sources	(Global)
Flexible data access, spatial data relationships through GIS	Provide interface from multiple systems, workstations	(Global)
Highway Advisory Telephone (HAT)	Provide public access to real-time traffic information (audio)	1
Highwav Speed Emissions Monitor	Monitor vehicle air quality using new technologies	(Global – each ATMS)
Interactive Travel Information Terminals (Kiosks)	Provide en-routelpre-trip Information at transportation center 8	Ea.rail/transfrats, airport, 5 per transfer/raita plue 5 add'l
In-Vehicle Navigation/Route Guidance Support	Provide data and Info to be utilized for in-vehicle systems	(Global -- support 3rd party)
Radio Data Systems (RDS)	Transmit Traffic/Data Info to public	(Experimental – – coordinate wlth 3rd party vendors)
Silent Radio	Transmit Traffic/Data Info to public	
Smart Corridor Strategies (Interagency In nature)	Reduce Recurrent/Non-Recurrent Congestion, Balance Flows	
Surveillance Hellcopters	Provide ah-based surveillance Information	1 hellcopter / 100 sq. miles
Tow Trucks – – Contract Tow	Reduce incident duration/facilitate clearance	(Global)
User fees charged to 3rd parties (dissemination)	Source of revenue for operation of IVHS facilities	$0 per year fee / 3rd party user
En Route Information Signs on Buses	Provide en-route information	1 per bus
Pre-Trip Planning Aids (transit)	Provide pre-trip information (general)	All CAN, kiosks, BBS
Pre-Trip Transit Info (real-time)	Provide pre-trip information (based on reel-time traffic/schedules)	All kiosks, BBS

* Location Crlteria as per the followlng:

Smart Corridor Statewide Study, 1990
District 4 Traffic Operations System, Operational Procedures and Strateglea Conceptual Design Report, 1992
Proposed District 12 Traffic Operations System Master Plan, 1992
Orange County TOC Study, 1991

5.8.1 - Information

5.8.1.1 - Traveler Information Database (TID)

All information regarding real-time traffic operations, including congestion measures, incident status, and public transit vehicle location and schedule data, are to be coordinated in a central Traveler Information Database (TID) located at the TIC. The database would be configured as a Geographic Information System (GIS), capable of receiving real-time information through the use of direct links to all agency traffic management systems, plus other data sources including the CHP, local police departments, and agencies adjoining Orange County, as well as a super-regional and Statewide system developed by Caltrans. This global clearinghouse will allow for dissemination of data over either broad or specific areas, and will by its nature assure consistency of information transmitted over various mediums, as presented below.

5.8.1.2 - Enhanced Media Interface

The coordinated TID would provide a unified, consistent information source for media information, including real-time traffic reports on local radio and television, plus road work and road closure information which could be accessed by the print media as well. Specific media servers for graphical (i.e., color congestion map) and text information (e.g., incident status, roadway closures, planned events) would be included.

5.8.1.3 - Cable TV for Pre-Trip Planning/Real-Time Data Display

For “on demand” information regarding real-time conditions, the use of a dedicated community access television (CATV) channel over local cable systems will be incorporated. Similar systems provide local and freeway traffic information within the City of Anaheim, and a similar system has been implemented by Caltrans District 7 and the City of Los Angeles to show freeway conditions in the region. Maps provide color-coded maps (green indicates no congestion, yellow is moderate, and red indicates heavy congestion). The level of information (e.g., local area covered, regional area covered) would have to be determined based on a coordinated local and regional agreement with local agencies and cable franchises; use of either central or local dissemination points and video servers (connected to the Central TID) would be considered based on agency requirements regarding control of information and data over the local cable system.

5.8.1.4 - Highway Advisory Telephone (HAT)/Dial-Up Services

Dial-Up information available to phone users is made feasible through use of the TID, which can collate information from different sources. Through the use of a Voice Response System (VRS), this information can be reconstructed and presented through the use of voice-digitization techniques. Users calling from either conventional or cellular phones would have access to desired traffic information through the use of touch-tone phone menus. Information could be oriented toward both visitor/tourist information (e.g., ingress, egress from John Wayne Airport or Disneyland) as well as commuters (conditions on specific freeways or in specific areas). A third-party vendor is currently in the process of developing a service (paid through advertising during the messages) which would provide “Point A” to “Point B” traveler information as selected by the user. Use of a central TID would greatly enhance the reliability and accuracy of such third-party services, and the opportunity would exist for the agencies operating the IVHS system to charge user fees for repackaging of this information.

5.8.1.5 - Interactive Information Kiosks

The use of interactive kiosks is particularly helpful to travelers away from home, either at an employment, retail or entertainment center, or at a multi-modal transportation facility. Kiosks can provide not only traffic information maps (similar to those for cable TV) selectable by a user menu, but important transit information as well. For locations at transit centers, the interactive kiosk could provide real-time transit arrival information, including information on connections and desired routes. The interactive system could be coordinated with an automated fare collection feature to provide an integrated information and route selection/fare collection system for transit users.

Six rail stations (San Juan Capistrano, Mission Viejo, Irvine, Santa Ana, Anaheim and

Fullerton) along the commuter rail network will provide transfer capabilities to buses in the near term. An additional dedicated bus transfer point is operational near Newport Center in Newport Beach.

The near-term architecture includes one interactive kiosk per rail station or transfer point. Two existing kiosks are in use in conjunction with Anaheim's Traveler Information System, and are located at a major hotel and at a major office building. As kiosks in private buildings are not considered a high priority by local agencies, these are thus assumed to be "private" or third-party devices. Assuming two kiosks at John Wayne Airport, plus at least four others in key public sites in the County, the total number of kiosks in the County over the near term would be 15.

5.8.1.6 - Pre-Trip Transit Information

Pre-trip transit information could be disseminated through any or all of three methods presented elsewhere in this section. One method, use of a dedicated CATV channel, could utilize real-time transit (bus or rail) location information compared with schedules, presented as a permanent side bar or text box. A second method would provide an option, utilizing interactive bulletin boards or kiosks, to access real-time transit location information. An estimation or comparison of auto travel times compared with estimated transit travel times could be presented for various origin-destination pairs or calculated based on user-input origin and destination information. A third method is to provide real-time transit information as a dial-up service in conjunction with HAT or third-party dial-up information services.

This element will thus be considered as a feature of other information elements in the IVHS Architecture.

5.8.1.7 - Support of Bulletin Boards/Videotext and Graphics

A dial-up bulletin board system (BBS), providing map graphics and text information, could be supported by a server which manipulates information from the TID and presents information to the users as requested by interactive menus. The bulletin board should require only that a PC user have a modem (e.g., 1200 bps minimum) and a compatible communications package (GUI or non-GUI) such as Crosstalk or SmartCom. The architecture assumes that such a bulletin board server would be provided at the TLC, connected into a local area network (LAN) with the Traveler Information Database (TID); however, local agency BBS systems are possible depending on the level of local information and capability desired. The City of Anaheim is developing a local BBS system under TSM funding for a traffic system expansion along La Palma Avenue and the SR91 Freeway.

5.8.1.8 - Support of Third Party Information Systems

Third-party information systems, for the purpose of the IVHS architecture, consist of devices developed by private entities with transmit traffic information directly to the user. Such devices include Traffic Channel, which provides real-time information to a hand-held electronic organizer. Another information system is Silent Radio, which provides scrolling text information to private businesses or facilities, ranging from restaurants and bars to office and hospital waiting rooms.

The modularity of the TIC's Local Area Network (LAN) would allow for connection of data servers which directly support various third party information systems. These servers could either be standardized by the operational agency and in turn require standard protocols from third-party information system vendors, or the third-party vendor could provide a data server on the LAN to support his system. The third-party vendor, on the other hand, would be responsible for maintaining his connections and peripherals associated with the severs, and the protocol to his devices may be proprietary in nature.

It is assumed for the near-term architecture that standard data servers at the TIC is provided for support of third-party information systems.

5.8.1.9 - Support of In-Vehicle Svstems (Private and Public Transit)

Support of in-vehicle systems can take the form of several different types of systems. These include the following:

- In-Vehicle Navigation Systems utilizing internal map and positioning software along with real-time data collection capability through vehicle-roadside protocols or via unbounded technologies such as Radio Data Systems (RDS).

- Voice, text or data information utilizing Radio Data Systems (FM sideband frequencies) receivers or Secondary Audio Program (SAP) television signals. The product "Auto-Talk" utilizes SAP and is currently operational in the Los Angeles area utilizing manual collation and broadcast of Caltrans freeway information using live broadcast personnel.

The primary type of server function required is to provide link congestion information in data form. Processing and presenting the data can be done either through the in-vehicle processor or some third-party automatic and manual processing (e.g., Auto-Talk's personnel collating and broadcasting traffic information by zone).

The in-vehicle server function could thus be considered a task included with a separate server or as part of a server which handles other information systems. This, however, would increase the processing and memory requirements of the server.

5.8.2 - Traffic Management

5.8.2.1 - Coordination of Interagency Activities

The architecture requires coordination of all IVHS activities and operations between all appropriate agencies in the County. This coordination is outlined in Chapter 8 (Agency Considerations). Such coordination is a pre-requisite for the development of Smart Corridor operational strategies.

5.8.2.2 - Smart Corridor Operations (Integrated Freeway/Arterial Management)

Smart Corridor operations consist of the coordinated utilization of freeway, surface street and global management and information elements and resources to maximize the use of available capacity and minimize overall delays. 95 miles of freeways and 271 miles of surface streets are identified in Orange County as part of Smart Corridors identified in the 1990 Statewide Study performed for Caltrans. The following benefits have been projected by the 1989 Conceptual Design for the Santa Monica Freeway Smart Corridor project:

Global Travel Time reduction	-	13%-15%
Fuel Consumption reduction	-	2.5%
Hydrocarbons emissions reduction	-	8%
Carbon monoxide emissions reduction	-	15%
Surface Street Intersection delay reduced	-	20%
Freeway Trip Duration reduction	-	12%
Surface Street Trip Duration Reduction	-	13%
Surface Street Speeds Increase	-	11%.

Execution of Smart Corridor Strategies may result in real-time adjustments to elements as follows:

Freeway:	-	CMS and HAR advisory and diversion messages Ramp Meter Rate adjustments Improved Coordination of Incident Management resources
Surface Street:	-	CMS and HAR advisory and diversion messages Route guidance via dynamic "Trailblazer" signing Adjust signal timing according to desired diversion strategy and fine-tune according to actual traffic demand May require adaptive signal timing techniques
Surface Street Operations Enhancements:	-	For other major arterials, including designated Super Streets and local arterials, some event-based and incident-management related operational strategies are necessary. These may involve use of changeable message signs as well as adaptive or traffic-responsive signal operations for the length of the roadway

Implementation of Smart Corridor strategies requires a combination of institutional agreements in which joint operations policies and pre-selected diversion routes are determined, and technical elements which enable coordinated operation between multiple agencies. The elements include the following:

- Expert Systems. Expert systems provide a means of assessing multiple data sources and multiple agency resources, in order to determine coordinated responses to congestion and incidents. The Architecture provides for the inclusion of an Expert Systems for each agency within a Smart Corridor which enable implementation of coordinated traffic strategies.

- Interties. These are interagency communications links which allow the sharing of video transmission and dynamic data between agencies. These are discussed in more detail in Chapter 7.

5.8.2.3 - Mutual Aid Agreements (Emergency Services)

An example of institutional coordination for incident response is providing priority access for emergency vehicles through a traffic network by preemption of traffic signals. This allows a band of consecutive green indications for emergency vehicles along their response route. For unincorporated areas of Orange County as well as 16 cities, fire protection is provided by the Orange County Fire Department (OCFD). Therefore, coordination of signal operations across municipal boundaries is essential for those adjoining communities or cities adjoining unincorporated areas which are utilizing OCFD services.

However; the use of municipal emergency services to assist in clearing major incidents, including those on freeways, may often involving crossing city boundaries. As part of operational policy discussions involving traffic management, discussions involving use of emergency resources are essential. In many cases, both formal and informal agreements are in place regarding interjurisdictional assistance. In making this policy more effective, consideration should be given toward coordinating signal pre-emption strategies. These can be covered under Mutual Aid Agreements.

5.8.3 - Global Accessibility

5.8.3.1 - Interagency

Through the use of inter-ties between agencies as well as a standard communication protocol, the IVHS Architecture will have the capability of providing agencies with any information desired concerning local, adjoining agency, or regional traffic conditions. Providing these interties allows the use of multiple data sources in formulating a multi-agency traffic management strategy, and thus becomes the backbone of the IVHS Architecture.

5.8.3.2 - Public

It is recommended that interactive terminals have the capability of operation in the most commonly used languages in the County other than English. At the minimum, interactive kiosks should have the capability of a menu interface in Spanish as well as English. Some areas such as Little Saigon could utilize kiosks with Vietnamese language information. Audio information for the blind can be made available through special braille instructions and touch-pads at the kiosk. Maps presented on CATV should be clear and concise enough such that they are understandable by all regardless of language read or spoken. Dial-up information services could also provide either separate phone numbers for Spanish-language information or a separate choice of language.

5.9 FUTURE EXPANSION

5.9.1 - Midterm

The recommended near-term architecture contains the basic structure to evolve with futures technology without requiring major changes. The following sections discuss the capabilities that are anticipated to be feasible in the mid-term and their incorporation into the architecture. The gradual addition of enhancements as they become cost-effective and as components are replaced or added will increase the effectiveness.

5.9.1.1 - Overhead/Roadside Detectors to Replace Loops

Current systems (i.e., inductive loop) do a reasonable job of measuring congestion, but future sensor technologies will provide a greater range of specific measurements, particularly speed and other characteristics. These sensors will be gradually incorporated into the architecture as they become cost-effective, either for system growth or as older sensors fail. Newer, above ground systems (e.g., radar, microwave, acoustic) do not need to be buried in the pavement, but can be mounted above the roadway or at the roadside. This means that maintenance is easier, faster, and less disruptive. Construction costs are also reduced.

5.9.1.2 - Proactive Congestion Management

As expert systems for traffic management are implemented and historical information and and pattems are developed, a more proactive approach to congestion management becomes possible. This approach results in anticipating traffic flow conditions rather than merely reacting to previous conditions, based on the system's knowledge of operations. The expert systems can use the more refined information to assess the situation beyond the current data. In particular, the combination of improved sensors and intelligence will allow the prediction of developing conditions, rather than establishing a current condition. If congestion is approaching an unacceptable level, the expert system can then take actions which allow the various IVHS agencies to inform and/or divert the traffic.

5.9.1.3 - Real-Time Multi-Mode Routing.

The above capabilities form the basis for pre-trip or in-vehicle route planning. Once the system is able to predict travel times between an origin and a destination based on predicted level of service over the length of the trip, it can give a traveler a recommended route based on real-time conditions. The use of AVL for transit will allow the system to know the location of all transit vehicles. This can be incorporated into the predictive algorithms, giving real-time expected time of arrival of the transit vehicles. By using the predicted transit link times, route planning becomes multi-modal. For example, the traveler may be told that a bus will be arriving at the comer in 5 minutes, and that even with a transfer it will take him to his destination in less time than would driving in the current congestion. In-vehicle systems will most likely be in use in this period, and through two-way communications they could take advantage of the information. For example, a motorist on the freeway might be informed that he is approaching a park-and-ride facility where he can catch a train to his destination rather than sit in congested traffic. Ridesharing could be enhanced through electronic notification to motorists of someone else wanting to go to the same destination. Such a capability would support those with irregular work hours who wish to carpool and use the HOV lanes.

5.9.2 - Long-Term Additions/Enhancements

The long-term advances will tend to be more autonomous, or vehicle-oriented in nature. Such elements include the following:

- Platooning
- Advanced in-vehicle information
- Transmitting in-vehicle vision systems

While the vehicle is not an integral cost component part of the architecture, the long-term architecture will provide the maximum amount of support and interaction with systems provided by various vendors in vehicles. Planning for this phase of the architecture requires an examination of Advanced Vehicle Control Systems, or AVCS. The benefits of such systems are as yet unknown due to the experimental nature of the technologies at this time. As these systems are tested, implemented and shown to be reliable, a better idea of the benefits and feasibility will be developed in the future. Chapter 6 provides a summary of in-vehicle sensors and other AVCS techniques.

Most of the major advancements needed to implement AVCS must be made in the vehicle. The design of the architecture of the infrastructure for AVCS should concentrate on the following:

1. Ensuring that vehicle-to-infrastructure communications bandwidth and protocols can support the required exchange of information.

2. Ensuring that the performance of sensors is compatible with the millisecond reaction times of vehicle AVCS components.

3. Ensuring that the data processing capabilities of the IVHS infrastructure is adequate to support the higher density and higher speed of traffic that will occur when AVCS is implemented.

6 The State-of-The-Art in IVHS

6. THE STATE-OF-THE-ART IN IVHS

This chapter provides a technical overview of IVHS elements, focusing on these techniques for initially defined in Chapter 2 and incorporated into system architecture in Chapter 5. These are discussed based on the previously-defined IVHS functional areas:

- Surveillance
- Communications
- Traveler Interface
- Navigation/Guidance
- Control Strategies
- In-Vehicle Sensors
- Data Processing

These areas and the enabling technologies are examined in further detail below, and related where necessary to the recommended applications for Orange County.

6.1 SURVEILLANCE

The purpose of surveillance is to obtain real-time operational infomation from the roadway network and from the vehicles along the network. This real-time operational information may be used for the following purposes:

- Congestion Measurement
- Locating an Incident
- Device Status
- Emissions Measurements
- Measurements for Transportation Planning Purposes
- Environmental (Weather) Measurements

6.1.1 - Data Requirements

Traffic flow along a segment of roadway can be described in terms of the following parameters:

- Volume - a measure of traffic demand; the number of vehicles passing a point (i.e., detection zone) during a specified time period

- Occupancy - a measure of traffic density; the percentage of time that vehicles are present in the detection zone

- Speed - a measure of rate of motion of the vehicles (e.g., miles/hour); typically, the average speed of all vehicles passing through the detection zone

- Average Vehicle Length - a method of classifying the different types of vehicles (by length) passing through the detection zone

These attributes can be used by the system to define the demand level, the utilization of capacity, potential incident (or other bottleneck) locations, and the level of service or performance or network segments. The information can be used also within system algorithms such as incident detection and travel time, and calculation of signal timing parameters. Additional traffic flow descriptors -- such as vehicle locations and identification roadway conditions, vehicle weight, number of axles, etc. -- may also be required by a system. These additional applications may be appropriate for transit management, automated toll collection, and freight movements.

6.1.2 - Technologies

Three types of data collection devices are available. These include:

- Static (roadway-based)
- Mobile (vehicle-based)
- Visual (use of live video cameras)

Exhibit 6.1 examines the capabilities of each of these data collectors in terms of the technologies available currently or under development. The Project Team intends this table to be a comparison of techniques only. It is expected that a multiplicity of these technologies will be incorporated into the County-wide IVHS Architecture. Given a uniform set of functional requirements, it is emphasized that reliability and accuracy are extremely important. Meeting these requirements will allow the production of information of uniform quality and functionality.

EXHIBIT 6.1

MONITORING / DETECTION TECHNOLOGIES

Type	Technology	Observable Data	Mounting		Cost	Installation	Reliability	Accuracy
STATIC	Inductive Loops	Counts, Presence, OCCS (Speed, Density, Axles w/ algorithms)	Embedded In road		Low- Medium	Moderate	Moderate	Medium-High
	Plazoelectric	Counts, Speed, Weight	Embedded In road		LOW	LOW	High (est.)	High
	Radar	Counts. Presence, Occs, Speed Density	Overhead or side of road		LOW	LOW	Moderate (est.)	High
	Passive Infrared	Counts, Presence, Occs, Density	Overhead or side of road		LOW	Low	Moderate (est.)	Medium-High
	Active Infrared	Counts, Presence, Occs, Density	Overheadoside of		Low	Low	Moderate (est.)	Medium-High
	Acoustic (audible)	Counts, Presence, Occs, Density (Speed with multi-sensors)	Overhead or side of road		Low	LOW	Moderate (est.)	Medium
	Ultransonic	Counts. Presence, Occs, Speed, Density	Overhead		LOW	Low	High (est.)	Medium
	Video Image Processing (VIP)	Counts, Presence, Occs, Density, Q. Length, Detect Incidents	Overhead or side of road		Medium-High	Low	Moderate (est.)	Medium-High
	Magnetic	Counts, Presence, Occs, Density (Speed with multi-sensors)	Embedded in road		Low	LOW	Moderate (est.)	Medium
MOBILE			ROAD	VEHICLE				
	AVI (Bar Code)	Weight, Axles, other identification or dynamic information	Reader on side of road	Bar Code	Low	LOW	LOW	Moderate-High
	AVI (Inductive Loop)	weight, Axles. other Identification or dynamic Information	Embedded in road	Transmitter	High	Moderate	Moderate-High	Moderate-High
	AVI (Microwave or RF)	Weight, Axles, other Identification or dynamic Information	Reader on side of road	Transmitter	High	LOW	High	Moderate
	AVI (Surface Acoustic Wave)	Weight, Axles, other Identification or dynamic Information	Reader on side of road	Transmitter	Medium	LOW	Moderate	Moderate
	AVI (Image Processing)	Read License Plates / ID's	Overhead or side of road	ID/License Plate	High	LOW	Moderate	Moderate-High
	AVL (Sign Post)	Speed, Direction, Location, ID. Dynamic Info	Radio transmitter, side of road	Transceiver	Low	Low	N/A	N/A
	AVL (Loran C)	Speed. Direction, Location, ID. Dynamic Info	Centrailec Transmitters	Transceiver	Low	LOW	N/A	N/A
	AVL (Dead Reckoning)							
	with Digital Map Position	Speed, Direction, Location, ID, Dynamic Info	Transmitters, side of road	Wheel Sensors, Compass	Low	Medium	N/A	N/A
	with Satellite Correction	Speed, Direction, Location, ID. Dynamic Info	Single Satellite	Wheel sensors, Compass	Low	Medium	N/A	N/A
	AVL (Global Positioning Satellite)	Speed Direction, Location, ID. Dynamic Info	Microwave to Multiple Satellites	Transceiver	Medium	High (GPS)	N/A	N/A
	AVL (Radio/Multiple Access)	Speed, Direction, Location, ID. Dynamic Info	Centralized Transmitters	Transceiver	Medium	LOW	N/A	N/A
	Smart Cards	Rider ID. Origins, Destination based on transit location	Carried by travelers. Readers a Collection Facilities, other sites	Transit Vehicles, Toll	Medium	Medium	N/A	N/A
VISUAL	Closed-Circuit Television (CCTV)	Qualitative observation of flows, congestion, Incidents	Overhead of side of road, portable		Low- Medium	Low- Medium	Moderate-High	N/A
	Stationary Camera	Photogaph specific vehicles, license plates	Overhead or side of road		Low	LOW	N/A	N/A

Type – Static, Mobile, Visual
Technology - (Description)
Observable Data - Count, Presence, Occupancy, Speed, Weight, Axles, Density, Queue Length, Direction, Other
Cost - Low (<Slok), Medium ($10K-30K), High ($30K)
Field Installation – Simple (minimal field construciton) Moderate (Limited Condult) Extensive (New Conduit, Complex Comm. and Software Requirements)
Reliability – High (>1 year MTBF), Medium (8 months- 1 year MTBF), Low (<8 months MTBF), N/A (Not Applicable or Not Available
Accuracy – High (measures most vehicles and data), Low (measures some vehicles and data), N/A (Not Applicable or Not Available)

6.1.2.1 - Static Devices

Static devices can encompass in-pavement, overhead-mounted, and machine-vision technologies, as well as the roadway-based component of Automated Vehicle Identification (AVI) systems. Examples are discussed briefly below.

In-Pavement Detectors

The most common of this type is inductive loop detection, which has been the predominant form of surveillance technology for almost 30 years. Loop detectors consist of a electronically-tuned loop of wire buried in the roadway. Detections of vehicles occur when each vehicle passes over the loop, thus decreasing the inductance during the interval. Loop detector reliability is often a function of design, installation and weather conditions. Improved sealants, loop-wire casings and embedded preformed loops, while more expensive, are also more reliable.

Other in-pavement detectors include magnetic detectors and piezometric devices. Caltrans recently has also demonstrated (through their INRAD experiment with Cal Poly San Luis Obispo) the use of the loop detector's electronic field as a radio transmitter, such that roadway congestion information can be transmitted to vehicles equipped with low-power receivers and in-vehicle displays.

Overhead Detectors

Installation of the detection unit above or to the side of the roadway permits maintenance activities to be performed with minimal disruption to the traffic flow. Moreover, these overhead-mounted detectors can generally remain operational during roadway reconstruction and rehabilitation activities that usually destroy loops and other in-pavement devices.

One potential drawback with these technologies is that their optimum placement is (typically) directly over each lane; and for such an installation to be cost effective, an existing overhead structure (e.g., overpass, sign support, etc.) is required. The location, spacing, and placement of these existing structures can impact the effectiveness of the surveillance subsystem. Another concern is that most of these technologies have not been completely proven in terms of .

accuracy or long-term reliability. However, operational tests involving many of these surveillance technologies, plus an FHWA-sponsored research effort to field test and evaluate these detectors, are underway. It is anticipated that many of these devices will be viable and proven candidates for IVHS-based systems by 1994.

Devices of these types are presented below:

Radar Detectors direct a continuous wave of low-power microwave energy toward an area of roadway at a 45 degree angle. As vehicles pass through the beam, the energy is reflected back to the sensing element which measures the speed based on the Doppler effect.

Wide-beam radar detectors provide the capability of counting a full approach or roadway, while narrow-beam detectors are used per vehicle lane.

Microwave Detectors are very similar to the radar detectors in that they transmit microwave energy toward an area of roadway from an overhead-mounted device. Instead of measuring a vehicle's speed using the doppler effect, the microwave detector measures the time it takes for a transmitted pulse to arrive at the road or a vehicle, then be reflected, and return to the detector. The presence of a vehicle is denoted by the difference in the time of arrival of the pulse when a vehicle passes through the field of view, as compared to the time of arrival of the pulse from the road surface. The detectors can either be side-mounted or the roadway. The latter is especially useful for lane-specific data collection, since large vehicles would not interface with measurements of vehicle movements behind. However, this configuration is also more costly.

Ultrasonic Detectors include an overhead-mounted transducer which transmits sound waves (at a selected frequency between 20 and 65 Khz) into an area defined by the beam width pattern of the transducer. A portion of the energy is reflected from the road surface or a vehicle in the field of view. The detector transmits a pulsed waveform and measures the time it takes for the pulse to arrive at the vehicle and return to the transmitter. This permits the detector to measure the height profile of a vehicle, thereby providing classification data in addition to volume and occupancy.

Infrared Detectors currently marketed consist of both active and passive models. In the active system, detection zones are illuminated with low power infrared energy supplied by light emitting diodes (LEDs) or laser diodes. Real-time signal processing techniques are used to analyze the received signals and to determine the presence of a vehicle.

The passive infrared detector measures similar traffic parameters. It uses an energy sensitive detector element to measure the change in energy emitted when a vehicle enters the field of view. The source of this energy is blackbody radiation due to the non-zero temperature of emissive objects.

Several disadvantages of infrared detectors are often cited. Changes in light and weather will cause scatter of the infrared beam and received energy. Their reliability in high traffic flow conditions has also been questioned, but they have been used successfully on the San Francisco-Oakland Bay Bridge to track the end of queues. They are side-mounted on the bridge at 600 foot intervals.

Passive Acoustic acoustic detector "listens" for vehicles as they pass through a detection zone -specifically, identifying the unique acoustical signature of engine noise or tires on the pavement. This is a very new detector technology with as yet no installations. A prototype is currently being tested at a location on the New Jersey Turnpike.

Video Image **Processing Systems (VIPS)**

i

VIPS technology uses microprocessor hardware and software to analyze "video" images of the roadway, and to extract real-time traffic flow data (e.g., volume, occupancy, speed, classification, etc.). With current VIPS systems, "pseudodetectors" are identified within the camera's field-of-vision by the user. Every time a vehicle enters or crosses this detection zone, a detection signal (i.e., presence) is generated which can then be processed to provide volume, speed, classification, and occupancy measurements.

VIPS offers several advantages -- it does not require installation in the pavement, and multiple detection points covering several lanes can be defied within a single camera's/sensor's viewing area. Potential concerns with VIDs are summarized below:

- Night measurements (occupancy and classification not possible except with low-light sensitive cameras or where area is very well-lighted).
- VIPs camera placement may result in occlusion -- when the image of one vehicle partially or completely masks the image of an adjacent vehicle. Cameras are to be mounted high above the roadway and at an angle such that this is minimized.

- Cannot combine VIPs with CCTV camera functionality. When a CCTV camera is panned, tilted, or zoomed to view an incident or other congestion -- the pre-set detection zones are lost.

- The cost of a VIPS system -- the camera, microprocessor, interconnecting cabling -- is very expensive relative to other detection technologies. The average cost of a single VIPS installation is $40,000-$50,000.

VIPS is rapidly becoming a "proven technology", with systems now being marketed by several vendors, and recent tests showing vehicle detection accuracy in excess of 95%. It is anticipated that future VIPS will provide greater functionality, including tracking individual vehicles, measuring speeds directly as an output of the vehicle tracking process (as compared to the current method of emulating loop pairs), and identifying congestion and incidents.

Detector Data Processing

A major issue concerns how and where the data from the roadway detectors are processed. The key consideration is flexibility. Given the rapidly changing detector market, an IVHS-based system must be capable of measuring traffic flow utilizing several different detector technologies, while also providing this real-time information to the control center in a single, standard format. In this manner, the system is not locked into a specific technology or vendor. New detector technologies can be integrated into the system as they become available (and proven), while the processing at central remains consistent.

Most roadway management systems process the data in the field, and then transmit the data to the control center using a single system-wide format. The detector data processors can be of any microprocessor form, including Type 170 controllers installed at each detector station. Firmware provided for the processors typically accomplish the following processing tasks:

- Accumulate traffic flow measurements and compute other parameters from each detector over a specific time period (e.g., 20-seconds to l-minute).

- Perform initial error checking of the data (e.g., comparing the accumulated flow measurements to user-defined over- and under-thresholds).

- Format the preprocessed detector station data and error codes for transmission to the control center. The central computer polls each detector station once every time period, which responds with the accumulated traffic measures. The data format should be consistent between stations, and should include the following information:

  - detector station identification
  - volume by lane (actual count)
  - occupancy by lane
  - average speed by lane
  - average vehicle length by lane
  - cumulative volume by lane (vehicles/hour)
  - percent occupancy by lane (percent)
  - cumulative average speed by lane (MPH)
  - smoothed average volume for mainline (vehicle/hour)
  - smoothed average occupancy for mainline (percent)
  - smoothed average speed for mainline (percent)
  - smoothed average vehicle length for mainline
  - detector failures

6.1.2.2 - Mobile Devices

Three types of mobile devices are discussed in the following:

Automatic Vehicle Identification (AVI)

Automatic vehicle identification (AVI) provides electronic reading and recording of a vehicle's identity as it passes specific points, without requiring any action by the driver or an observer. Information that identifies a vehicle is encoded onto a vehicle-mounted transponder (or toll-tag). As the vehicle passes a site with an AVI antenna/reader, the tag is activated to transmit the coded data to the antenna, and then to an adjacent roadside reader or processor. Several different technologies and procedures are used in AVI systems, for example:

- Tags may be bar coded, and then scanned using optical lasers or infrared. The most versatile systems use RF or microwave transmissions to energize and read the encoded tag.

- Antennas can be mounted above or to the side of the roadway; while some systems utilize an inductive loop embedded in the roadway as an antenna. The antenna mounting obviously impacts the placement of the vehicle tag.
- Some AVI systems are "read-only"; while others provide two-way data transmission between the reader and the tag (e.g., the reader can also transmit data to the tag which is encoded in a "scratch pad" for subsequent reading by a downstream antenna).

The primary applications for AVI are to automate toll collection without stopping (known as electronic toll collection - ETC); automatic equipment identification to identify rolling stock and inventory assets (e.g., rail cars, highway trailers) in the rail, shipping, and motor freight industries; for truck weight and safety enforcement regulation; and for commercial vehicle revenue collection and curb usage regulation at airports.

AVI technology is being implemented to aid in electronic toll collection (ETC) for the new Toll Roads now under construction in Orange County. Approximately 150,000 AVI tags are expected to be issued for the Transportation Corridor Authority (TCA) toll roads. Nationally, over 100 million electronic toll transactions annually are now processed automatically via electronic toll collection. Electronic toll collection enables roughly three times as many transactions per lane per hour as is currently done with manual toll collection. Therefore, traveler delays (and air pollution) can be significantly reduced, along with a concomitant reduction in the labor resources needed for toll payment transactions.

Another MB-related use of AVI involves commercial vehicle operations. An example of this application is the Crescent/HELP (in California along I-5 north of Los Angeles and I-10 east of Los Angeles) projects, in which AVI will be implemented. Certain trucks will be equipped with identification transponders or tags, which can be read at highway speeds to automatically identify the vehicle as to weight, credentials and appropriate certifications.

Currently, two separate national groups are addressing AVI standardization issues. Reaching an acceptable consensus for these standards will not be easy, and will likely take considerable time. In the meantime, regional entities such as TCA and Crescent/HELP are proceeding on independent courses. It will be desirable to develop a standard for AVI which can be adopted throughout (at the minimum) the Southern California region (including Orange County) in the near term.

Smart Cards

Smart Cards are similar in principle to a bank ATM card; but smart cards offer many more capabilities in that they function as portable minicomputers, containing both microprocessor and memory elements. Smart cards may be used by travelers to board transit vehicles and to pay tolls, parking fees, and cab fares without cash because the necessary identification and billing information is automatically read from the card Smart cards may also be used to identify origins and destinations of passengers by using a reader system mounted at entry and exit doors. Other applications can include vehicle maintenance, driver management, and fleet management. The applications of Smart Cards in Orange County will include the ETTM system for the new Toll Roads, as well as for fare payments on transit vehicles.

Automatic Vehicle Location (AVL)

Automatic Vehicle Location (AVL) systems have three basic elements:

- location determination
- communications for repotting vehicles' location to a central facility (typically a dispatcher)
- displays of vehicles' locations at a central site and elsewhere on an information network

Real-time information regarding vehicles' locations and progress may be utilized in IVHS-based systems to track schedule adherence of transit and commercial vehicle fleets, thereby improving vehicle response times; to provide transit information (e.g., expected arrival/travel times) to travelers at bus stops, transfer points, and at home/office; to enable the optimum selection of dispatched vehicles; to improve safety of personnel and cargo (via operator-activated/automated MAYDAY alarms); to indicate roadway and traffic conditions (i.e., vehicle probes); and to generally improve the efficiency of fleet operations and management.

Several AVL-based systems are on the market. These include devices used primarily for transit management as well as for tracking stolen vehicles. An AVL system can also be utilized for tracking of Freeway Service Patrol (FSP) vehicles.

AVL tracking utilizes a number of vehicle-roadway communication and location techniques which are outlined in Section 6.4 on Navigation and Guidance.

To summarize the use of AVI and AVL as vehicle probes for traffic management and information, a number of issues are to be considered:

- Population of AVI-tagged or AVL-equipped vehicles. In the near-term, it is expected AVI will be utilized for toll collection and for private fleet management. AVL will be initially focused on transit vehicles as well as fleet management for Freeway Surveillance Patrol and other government vehicles.

- Reader Spacing - for AVI, it is assumed that one-mile reader spacings will be required.

- Information ascertained from AVI and AVL for traffic information use. At the minimum, it is expected that reader location, time and vehicle ID will be the data obtained from AVI, and location coordinates, time and vehicle ID will be obtained from AVL. Knowledge of personal information associated with vehicle ID must be kept in confidence such that an individual's right-to-privacy is not violated.

6.1.3 - Visual Devices

Closed-Circuit Television cameras has been used extensively in traffic management systems for roadway surveillance. In addition to its primary task of incident verification, CCTV may also be used for other surveillance functions in corridor management, including:

Freeways

- Monitoring traffic movements on the mainline, HOV lanes, and the entrance/exit ramps (e.g., driver response to various CMS messages, CMS message verification and fine tuning, HOV shoulder lane usage, compliance with ramp metering, etc.).

- Confirm the existence of a suspected incident that has been detected through other means, determine its nature and the appropriate response.

- Identify and detect stranded motorists.

Corridors

- If cameras overlook parallel surface streets, verifying that the local street system has operating capacity before implementing freeway diversion, and then monitoring system performance as diversion occurs.

Surface Streets

- Monitoring the operation of critical signalized intersections and evaluating the signal timing and related functions.

General

- Weather/hazardous condition observations

- Identify damage to system field equipment resulting from contractors, accidents, storms, etc.

It is noted that the principal purpose of CCTV is not to identify the occurrence of or congestion conditions of an incident -- it has been found that simply monitoring the video images does not result in early detection.

A major issue associated with the design of a CCTV surveillance subsystem is determining the appropriate coverage. Roadway segments requiring full CCTV coverage (i.e., no "blind" spots) generally experience high volume/capacity ratios and a high frequency of incidents. Full coverage is also useful during roadway rehabilitation and reconstruction activities. Current camera technology allows relatively clear viewing of l/2 mile in any direction, which translates to a nominal one-mile spacing between cameras on tangent. Closer spacings will likely be required, however, to overcome obstacles such as horizontal and vertical curves, extended overpasses/tunnels, and to improve the viewing of areas of specific interest. For those sections where full CCTV coverage is not required or cost effective to install, cameras may be installed at key locations such as interchanges and congested intersections.

6.1.4 - Other Surveillance Technologies

6.1.4.1 - Weather/Environmental

Several manufacturers offer in-pavement climate sensors which can provide the following real-time information:

- Surface temperature
- Surface condition such as dry, moist (dew), wet, wet with salt, ice (freezing alert)

These climate detectors are widely used at airport facilities to monitor runways. In a roadway IVHS application, the road surface information could be utilized for adapting the traffic management and control strategies (e.g., incident detection calibration factors, ramp metering rates) and for tailoring the traveler information (e.g., "ICY CONDITIONS AHEAD") to better suit the particular conditions.

As another example, LIDAR, which stands for Light Detection And Ranging, is an optical technology that may be used to measure air quality. LIDAR can define the location of a cloud of particles in a beam of light. These particles may be smog or water molecules. LIDAR can operate in the infrared or ultraviolet portions of the spectrum, or by using two laser wavelengths (DIAL - Differential Absorption Lidar). Such detectors may be used to process basic air quality measures and produce reports relating air quality to traffic flow conditions and IVHS strategies.

In Europe, the designers of the DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) program have incorporated algorithms which factor weather conditions into development of CMS and variable speed messages as well as ramp metering operations.

6.1.4.2 - Manual Call-In

Incident information can be obtained directly through call-in procedures. In Orange County, these include call-ins to CHP from "Cellular 911" (in-vehicle cellular phones) as well as from cellular call boxes along the freeway system and selected arterial roadways in rural areas. The IVHS traveler information function should provide the capability of access to incident location and type information for development of coordinated traffic response strategies, particularly for major incidents which are blocking lanes.

4.2 COMMUNICATIONS

If the data collection effort is the lifeblood of the IVHS system, then the communications network serves as the backbone of the system. If thought of as a single expense, the communications network will most likely be the costliest item in the architecture.

Communications links include the following:

- Links within Infrastructure (Central-to-Central, Central-to-field, field-to-field)
- Infrastructure-to-vehicle

This section will focus on communications links within the infrastructure. The infrastructure-to-vehicle links are discussed in greater detail in Section 6.4 (Navigation/Guidance).

The most important consideration in designing a large communications network is that to be economically viable, it must provide reliable service for twenty years or more. At this period in the communications industry, the extent of technological change, standards development and market restructuring presents a considerable challenge in identifying appropriate technologies.

The IVHS Architecture will require the capability of transmitting data, voice and video. The types of transmission between elements and the various transmission standards and protocols are identified in Chapter 7 (System Configuration for Information Sharing and Dissemination). However, presented below is a summary of enabling technologies in communications which will contribute to the IVHS architecture defined in Chapter 5.

6.2.1 - Data and Voice

Data and voice transmission technology is now virtually all digital and largely based on the T-carrier system and the synchronous optical network (SONET) standards in both public and private networks. In addition to transmission speeds, these standards also address chassis and racks, plug-in boards, interface, and connectors. This generally allows a second manufacturer' s equipment to be added to a given site without re-configuring the hardware. Moreover, several capable “network management” tools have been developed to support the T-carrier and SONET electronics. In addition to these “high speed” networks, another network protocol being adopted on a larger scale is the Integrated Services Digital Network (ISDN), which consists of 64-144 Kbps channels, equivalent to one-fourth of a T-l channel.

A significant development has also occurred in radio-based distribution systems by private companies. There is an emergence of radio technologies that re-use frequencies, or use frequencies heretofore impractical to obtain without the need for FCC licensing of each individual path or broadcast. This is creating a new communications market segment -- one in which equipment vendors provide air path solutions to what were previously wire and right-of-way problems. This market has just emerged, and it is being aided by the drive of traditionally defense-oriented corporations to apply their technological expertise in the civilian market.

6.2.2 - Video Transmission

Video images from CCTV cameras to a control center place the heaviest load on the communications network. Specifically, full-motion video requires 6 MHz (megahertz) of bandwidth per camera, as compared to a bandwidth requirement of only 0.005 MHz for a low-speed (1200 baud) data channel. Another consideration is that video is an analog source, while data communications and the T-Carrier and SONET Standards are digital. Accordingly, video transmission has typically been the most problematic element of communications network (and system) design.

Video transmission is best done over wide-band technologies utilizing dedicated microwave frequencies, coaxial cable and optical media (i.e., fiber optics). Developments have included fiber optic video multiplexers (which provide up to 36 video images over a single fiber), and fiber optic transmission equipment which permit analog video and digital camera control data to be transmitted over the same fiber.

In some cases, however, the cost of new cable and conduit for video may be prohibitive. An alternative is the use of digital data/voice media along with the means to “compass” the analog signal into a digital format. A coder-encoder (CODEC) unit can digitize the video image and compress the bandwidth such that the real-time picture may be transmitted over the telephone lines -- as well as other data communications media (e.g., radio, satellite) -- to another CODEC unit where the digitized information is converted back to an analog format for viewing on a television monitor. A reasonable degree of "full motion" (e.g., 10-30 frames per second) and resolution is maintained, even when there is significant motion in the video image, or the camera is being panned and tilted. The best video quality is associated with the highest transmission rates (typically 384 kilobytes per second or higher).

The most significant trade-offs with digitized video vs. analog video involve quality (full motion video tends to be higher quality and less "jumpy") as well as the cost of CODECs. Multi-channel CODEC's for trunk transmission of several channels are expensive ($40,000 each end) and require environmental video enclosures (i.e., heated, air-conditioned). Single-channel codecs are less expensive, but are suitable for small numbers of cameras only.

6.2.3 - Communication Media

At the heart of any communications subsystem is the transmission medium. Each communications medium has inherent characteristics -- such as frequency response and bandwidth, susceptibility to interference and noise, allowable baud rate, repeater requirements, physical constraints, etc. -- which determine its suitability for use in this architecture. These technologies are discussed below and summarized in Exhibit 6.2.

6.2.3.1 - Fiber Optics

Fiber optics cable has numerous advantages -- large capacity, immunity to electromagnetic and RF interference, a small flexible lightweight cable, and the capability to transmit data, voice, and video. The transmission equipment required is readily available in a competitive market. The capability for expansion is practically unlimited as fiber bandwidth is very large. In essence, fiber optics cable applies a solution to all of the network communication design issues.

The use of fiber optics requires a dedicated, owned communications network. This requires right-of-way and conduit throughout the network. Right-of-way is usually the limiting factor for private companies, but not for the State. The cost of installing and maintaining conduit, however, can be significant.

X = **Applicable**
C = Applicable with Data / Video Compression ($20,000 per end)
F = **Future**

EXHIBIT 6.2

COMMUNICATIONS MEDIA COMPARISON

Medium	Cost per Mile*	Additional Construction Cost per Mile (includes conduits)	APPLICATIONS			Maintenance and Training Requirements	**Comments**
			Data	Video	Voice		
Fiber Optics	$40,000	$135,000	x	X	X	Medium	Most flexible medium
Leased Lines	$7,500 construction $4,000 annual lease	N/A (Leased:	X	C	X	Low	Quickest medium to implement
Twisted-Pair Cable	$15,000	$135,000	X	C	X	Low	Proven as a data/voice carrier. Limited video use
Spread Spectrum Radio	$15,000 per hop	N/A (Wireless)	X	X	X	High	New application unproven for technology. FCC licensing not required
Microwave	$30,000 per hop	N/A (Wireless)	X	X	X	High	Needs FCC licensing, frequency
Satellite	$60,000 annual	N/A (Leased;	X	C	X	High	Needs FCC licensing, frequency. Requires compression of video
Cellular Radio	$45 /month $0.50 /minute Airtime Charges	N/A (Leased;	F		X	Medium	High costs for dedicated use, digital cellular trans-mission not yet implemented. High useage causes potential reliability problems

* 1) For Fiber Optics, add approximately $30,000 total for end equipment. Other media include end equipment in cost.

2) Leased and Wireless Media Costs are per link.

3) Number of hops required for Spread Spectrum and microwave are topography-dependent.

4) Costs referenced are per recent JHK projects in Anaheim and San Jose, CA, plus Draft Communications Handbook for Traffic Control Systems, FHWA, 1992.

6.2.3.2 - Leased Lines

Leased circuits have the flexibility and speed to apply to the communications system as trunk connections. Typical available leased circuits include voice grade/data grade analog (1200 bps), digital (56 kbps), T-carrier and SONET.

Leased telephone is a very reliable communications solution in that there is a grid redundancy element due to the general coverage of the carrier's network. One potential advantage over a dedicated network is that maintenance responsibilities are shifted to the telephone company. There are, however, a number of potential drawbacks with the leased approach, including:

- Freeway Access - The leasing agency is typically required to provide the telephone company with a conduit between the field cabinet and the nearest telephone facility. The required distance may be similar to the cost of conduit required for a dedicated network. However, these capital costs may be passed on to the client in the form of lease costs, versus a higher "up-front" cost as required with dedicated networks.

- Cost - The costs for a leased network do not end with the installation of the conduit. There is a monthly charge, and no guarantee that recurring charges will not significantly increase in the future. Several systems have converted from leased telephone to jurisdiction-owned communications because of previous rate increases and the uncertainty of future hikes. Contractual arrangements which fix rates at a specific level over on number of years are recommended.

- Video Transmission - As a result of the improvements in CODEC technology during the last few years, the transmission of video over leased telephone is not as significant of an issue as it once was. Nevertheless, use of leased facilities for video requires a dedicated T-l circuit, a CODEC unit with a Channel Service Unit/Digital Service Unit (CSU/DSU) at both ends of the circuit, and for many multi-channel CODEC designs, an environmental enclosure (with heat and air conditioning) to house the CODEC.

6.2.3.3 - Twisted-Pair Cable

Agency-owned twisted pair cable has been widely used for the low-speed transmission of traffic control data (e.g., between hubs and field elements), with the network configured with between 8 and 16 field drops on each two-pair (4-wire) channel. The exact number of drops depends on the amount of data to be transferred between central hub and the field locations, and the rate of transfer. Typical baud rate is 1200 bps. Voice can be carried on a single-pair.

Twisted pair cable is a reliable and proven technology. A properly designed and installed twisted pair communications system features reasonably low maintenance requirements in terms of the average time between failures, the average time to repair, and the necessary levels of skill and equipment. Like fiber optics, it does require right-of-way and conduit, the latter often resulting in significant costs.

Video transmission is possible on twisted-pair but requires repeaters every 3000 ft. to 3.6 miles, depending on the wire gauge. This is cost-effective when utilizing existing twisted pair facilities. There is no protection from Electromechanical Interference or Radio Frequency Interference (EMI/RFI) when using twisted pair cabling facilities for video, which is a major drawback.

6.2.3.4 - Spread-Spectrum Radio

One of the chief advantages of a radio-based communications subsystem is that no physical connection is required between the transmitter and receiver. This can translate into a significant cost savings over the capital intensive cost of installing a cable conduit network, or the unpredictable ongoing costs for a leased facility. One promising radio alternative is the use of a Spread-Spectrum radio. This technology is defined as “a means of transmission in which the signal occupies a bandwidth in excess of the minimum necessary to send the information; the band spread is accomplished by means of a code which is independent of the data, and a synchronized reception with the code at the receiver is used for subsequent data recovery”.

With spread-spectrum radio, the entire band (i.e., 902-928 MHz as designated by FCC) is available for use by all users. This is accomplished by “spreading” the signal over the entire 26 MHz spectrum (in the 902-928 MHz band), and requires that the receiver “lock-on” to the transmitted signal which adds to the efficient use of the available spectrum. Due to the spreading of the signal over a wide frequency range, electromagnetic noise (interference typically generated at a very narrow band width) has less effect on signal integrity. Any noise interfering with a spread spectrum signal will tend to obscure only a very small fraction of the entire band, and since the signal is divided and spread over the entire spectrum, the transmitted signal can still be reliably reconstructed at the receiver.

6.2.3.5 - Microwave

Microwave signals are radiated from an antenna and propagate through the atmosphere along a line-of-sight path. The frequencies used must be unique in that area to prevent interference from other microwave transmissions. Because of this constraint, microwave frequencies are licensed by the FCC, and it can be very difficult to obtain a microwave frequency allocation in crowded urban areas. When frequencies are available, they are usually in the higher frequency bands (18 and 23 GHz), which have reduced transmission distances.

Weather conditions and local topography determine the feasibility of microwave transmission as a communications medium. The effect of rain, fog or snow can attenuate/reduce the radiated power of the microwave signal, The Southern California region is ideal for microwave due to its mild climate while areas such as the Pacific Northwest, the East Coast and the Midwest are considered more difficult in the design of a microwave communications link.

Typical configurations for microwave communications can be point to point or point to multipoint, depending on the requirements of the network. The point to point network is one where the transmitter propagates the microwave signal to a receiver located at some distance (0.5 miles to 40 miles, depending on the frequency utilized). The point to multipoint system requires one transmitter propagating the microwave signal to multiple sites of receivers located in the field.

The utilization of microwave communications falls into two major categories. The first is an analog microwave system in which the method of modulation is typically FM (frequency modulation). This type of system is utilized for the transmission of video images (CCTV) which provides a full motion image. The second is a digital microwave system in which the method of modulation is typically TDM/TDMA (time division multiplexing/time division multiple access). This is an all digital system which is used for data and voice. The transmission of video can be accomplished but requires digital video compression techniques.

6.2.3.6 - Satellite

Satellite is similar to microwave in that both use some of the same frequencies for tmnsmission through the atmosphere. With satellite, however, instead of utilizing a line-of-sight transmission path, the signal is directed at a satellite transponder.

Satellite service has been available for many years for voice, data, and video transmissions. Very Small Aperture Terminal (VSAT) satellite systems use 14 GHz and the downlink (i.e., transmissions from the satellite to the earth) use 12 GHz The satellites themselves have a geosynchronous orbit above the Earth's equator, thereby appearing stationary in the sky and providing 2% hour a day coverage. These high-altitude satellites also avoid various earth-level interferences.

In addition to the satellite links, a central hub element and earth stations are also required to provide a VSAT-based communications network. The "Hub" may be located at a traffic management center, and serves as the focal point for communications between the remote sites and the control center.

The "earth station" is the communications component of a remote site. The earth station consists of an antenna, an RF transceiver mounted on the antenna, and a digital interface unit. For video applications, the digital interface unit is connected to the cameras central receiver (for pan, tilt, zoom) and a CODEC unit.

In general, the VSAT medium is ideal for long-distance communication links (e.g., communications between the Caltrans District 12 TOC and Sacramento) since the costs of leasing VSAT channels are independent of distance. In general, VSAT becomes cost effective relative to leased lines at a transmission distance somewhere in the range of about 300 miles.

Since VSAT lease costs are a function of the percent of time that the inroute/outroute link is actually utilized, this technology may also have cost-effective applications in a localized communications network where transmissions are required only on an as-needed basis, such as for CCTV that is only used as needed for incident verification.

Another potential use of VSAT is for communications where a dedicated cable network and/or leased telephone circuits are not readily available, or where a surveillance camera needs to be mobile -- for example, in conjunction with the maintenance and protection of traffic during roadway construction, and during major incidents in areas where CCTV is not available, but real-time video surveillance would be a great asset.

6.2.3.7 - Cellular Radio

Cellular radio is a technique for frequency re-use in a large radio communications system. It is mainly known by, what is its largest implementation by far, the mobile telephone network. Cellular radio is based on the concept of "cells" which are 2 to 20 mi. across, the center of each is a control radio which handles the network management functions including the assignment of frequency sub channels. A radio requests a frequency over a control channel and one is assigned by the cellular control system. The cellular layout allows frequencies to be re-used in non adjacent cells.

Due to the demand for car telephones there is a new, second generation of systems emerging which will be characterized by digital speed transmission and enhanced network control. The new system will provide greater bandwidth and frequency re-use capability. There is current development using this technique for data systems. However, new networks will likely have the same or similar rate structure making them unsuitable for constant (high-use) connections with fixed (as opposed to mobile) devices such as field hardware. On the other hand, the new cellular alternatives do appear to have potential for driver information transmissions such as in-vehicle navigation devices. (Refer to Section 6.4, "Navigation/Guidance".)

6.3 TRAVELER INTERFACE

The distribution of information to travelers will perhaps be the most visible function of IVHS in Orange County. Since a multitude of technologies exist for transmitting information and advisories to the traveler, it becomes important for the IVHS architecture to support the technologies through one consistent interface and data resource, so as to achieve consistency and the capability to monitor the information that is put out. The quality of the data that is disseminated will be an integral to the success of IVHS.

	TYPE OF TECHNIQUE	VISUAL	AUDIO
INFRASTRUCTURE	ROADWAY-BASED	Changeable Message Signs (CMS)	Highway Advisory Radio (HAR)
	NON-ROADWAY BASED	Graphics Displays - Cable TV Broadcast Display of CCTV images Teletext Silent Radio Videotext/Bulletin Board Systems	Highway Advisory Radio (HAR) Pager Technology Radio Broadcast (from Media Interface) Digital Radio Receiver or Radio Data System
VEHICLE	PRIVATE OR COMMERCIAL VEHICLE	In-Vehicle Displays - Graphics - Text - Advisory Messages	Digital Radio Receiver or Radio Data System
	TRANSIT VEHICLE	In-Vehicle Displays (Messages Graphics)	Information from Driver or Digitized Voice

EXHIBIT 6.3

SUMMARY OF TRAVELER INFORMATION TECHNIQUES
Visual or Audio

There are two primary categories of information to be disseminated: Pre-Trip and En Route. The character of this information differs with the intended "audience". For example, providing en route information to transit users requires a different type of information than that for private vehicles with in-vehicle navigation system.

To disseminate the information, a variety of audio and visual techniques are considered as candidate elements of the architecture. These are described in general terms in Exhibit 6.3. For both audio and visual information techniques, information techniques that are external to the infrastructure (i.e., vehicle-based or autonomous) are available as well as techniques which include components physically present along the roadway network (roadway-based).

The potential dissemination techniques required to reach the traveler for pm-trip and en-route information is described in Exhibit 6.4 in terms of both traffic and transit information.

6.3.1 - Interface Between Surveillance, Processing. and Traveler Interface

The accuracy and timeliness of the information disseminated to the public is largely dependent on the accuracy and quality of the information received from the field As is evident from Section 6.1 (Surveillance), this information may be received from a variety of sources and can cover an extensive number of parameters. However, in order to provide the desired information to the traveler, necessary actions and response techniques must be taken by the system. Also a reasonably detailed level of information must be coordinated to provide a single pool of information. This "Traveler Information Database" (TID) on a County-wide basis may be best implemented on a Geographic Information System (GIS), as described in Chapter 5 and in more detail in Section 6.7. The TID may consist of the following layers of data:

- Roadwav Traffic Data. This would consist of appropriate raw traffic data indicated by location and direction, including measured volumes, speeds and occupancies. Additionally, calculated Measures of Effectiveness (MOE's) could be included for defined sections of the IVHS Network. Such information may include estimated delays along a section of roadway as well as estimated travel times between specific points along the network.

	DRIVER LOCATION	ROADWAY-BASED	NON-ROADWAY BASED
	Pre-Trip		Highway Advisory Telephone (HAT) Pager Technology Radio Broadcast (from Media Interface) Broadcast Display of CCTV images Silent Radio Videotext/Bulletin-Board Systems Teletext Graphical Displays - Cable TV
PRIVATE VEHICLE	Start of Trip (Before congested roadway)	Changeable Message Signs (CMS) - Trailblazer - Surface Street Full-Matrix Highway Advisory Radio (HAR)	In-Vehicle Displays (ADIS) Radio Data Systems/Pager Technology Radio Broadcast (from Media Interface) Digital Radio Receiver (ADIS)
	On congested roadway, upstream of incident	Changeable Message Signs (CMS) - Freeway Full-Matrix Highway Advisory Radio (HAR)	In-Vehicle Displays (ADIS) Pager Technology Radio Broadcast (from Media Interface) Digital Radio Receiver or Radio Data System
	On diversion route	Changeable Message Signs (CMS) - Trailblazers - Surface Street Full-Matrix Highway Advisory Radio (HAR)	In-Vehicle Displays (ADIS) Pager Technology Radio Broadcast (from Media Interface) Digital Radio Receiver or Radio Data System
TRANSIT	At transfer points		Kiosks (Interactive Graphics)
	En route		In-Vehicle Displays (Messages, Graphics)

EXHIBIT 6.4

TECHNIQUES TO SATISFY SPECIFIC INFORMATION NEEDS

- Transit Data. This would include, at the minimum, schedule data for transit routes. Given location information from AVL, it should be possible to estimate times of arrival and travel times of transit for use in comparison with using private vehicles.

- Incident Data/System Actions. This would be a running log of system incidents as confirmed by System Operators (from one or more agencies). In response to these incidents, agencies may approve a number of actions. Such actions may include CMS and HAR messages, as well as route diversion strategies or actions to close an additional lane for incident clearance. These agency actions would be tracked by the TID and logged

The TID serves as a basis for taking the collected data and system responses as well as distributing the correct information to the appropriate servers for the various users and interfaces. It should be possible to monitor and edit the information contained in the TID. The Operator will then be able to edit information at one location rather than individually for each information subsystem. Thus, for example, Operators would not have to correct information being sent to the media and also to in-vehicle devices.

The continuing evolution and adaptation of advanced technologies is resulting in a significant number of new applications for dissemination. Such advancements have come in communication, display, and processing technologies, with the overall direction heading toward providing real-time traffic information, both as a component of the highway infrastructure (the Smart Highway, Street and/or Corridor) and as a component of the vehicle (the Smart Car). As the level of information improves, such inputs will be critical to the development of Automated Vehicle Control Systems (AVCS), which will need to rely very heavily on real-time information and operations strategies in order to be functional and useful. As a goal of the federal IVHS Act of 1991 (a part of the approved ISTEA transportation program), such systems am to be implemented on a test basis by 1997.

The following material provides a review of the “state-of-the-art” in traveler interface technologies.

6.3.2 - Media Communications

There can be at least three levels of media interface with the IVHS architecture. Each level provides a unique type of information such that they are complementary to one another.

6.3.2.1 - Text-Based Information

This information can be transmitted in the form of traffic status summaries, which could summarize traffic information for each freeway, including incidents, delays, travel times, and suggested alternate routes or transportation modes (i.e., transit). Text-based information can be transmitted via either dedicated or dial-up leased line. Information may be sent either on a non-interactive basis (e.g., teletype) or on an interactive basis, based on the selection of the desired information by the user from a menu. Frequency of update/refresh rate is dependent on how the information is retrieved and updated.

6.3.2.2 - Graphical Information

Graphical displays of traffic status provide an attractive and informative way of presenting information to the media as well as to the general public. Based on field traffic data and pre-set data thresholds, appropriate color-coding for parameters such as speed, occupancy, and volume can be utilized to represent traffic flow conditions for each data station along a freeway.

Caltrans Districts 7 and 12 utilize this type of display in their Traffic Operations Centers (TOC's). It allows the Operator to zoom in on particular portions of the network, or be able to view the entire network at once. The District 7 and 12 graphics also have the capability to monitor CMS messages by clicking on a CMS icon with a mouse-type pointing device. Currently, the graphics are shared with a number of local agencies, including the Cities of Anaheim and Pasadena, and will be shared with additional local agencies as part of current projects in Los Angeles, Santa Ana, and Irvine come on-line. In turn, Caltrans Districts 7 and 12 will be able to receive local signal system graphics information.

Graphical information may be sent from the IVHS network to the media via dedicated leased lines. However, software needs for the media users are greater than for text-based transmission, unless the data is sent in a non-interactive format such as the National Television Standards Committee (NTSC) RS-170 format.

Interactive graphics for media users involve the use of a graphics software and geographic database configuration that is identical or compatible with that of the IVHS architecture. The media users' PC equipment should have appropriate graphics enhancements for information reception. A typical set of enhancements includes use of a large screen with a special graphics driver card allowing high resolution. If selected media are permitted to transmit the interactive graphical data to the public, the media would be responsible for conversion of the RGB data to NTSC format for broadcast or cable TV transmission.

Non-interactive graphics transmission has been implemented in Anaheim and Los Angeles. This consists of broadcast images of the IVHS network displayed for a county-wide system. These could be sent either on separate channels for different TOS network areas (so the media or viewers could monitor one area continuously) or the images could be rotated in a "slide show" format and be transmitted on a single channel. This is analogous to "teletype" text transmission discussed above where the user receives information but cannot query the type or frequency of information to be sent.

6.3.2.3 - Video Information

If a video intertie with media is deemed appropriate, CCTV images (NTSC format) could be sent for those locations where incidents are present or for selected freeway locations. The amount of flexibility and number of images available to the media would depend on the resources available to multiplex the data for transmission to the media and what level of manipulation (switching, number of monitors, etc.) the media outlet(s) would have available.

6.3.3 - Changeable Message Sims (CMS)

Many recent advancements have been made in motorist display systems. The information provided by a CMS ranges from the most basic level (a fiied blank-out message indicating a specific recurring or non-recurring condition) to a medium level (dynamic route guidance using an adaptation of conventional route trailblazers or directional signing) to the highest level (dynamic, real-time congestion, incident, and best route information using full-matrix signs). Exhibit 6.5 shows potential applications for these different levels of signs.

The emphasis on freeways has been on providing the highest-level of information; in other words, full-matrix CMS. However, use of other types of CMS, particularly along surface streets parallel to freeways, is a high priority. The Smart Corridor integration with local roadway operations is considered necessary to improve traffic flow through those corridors. An overall strategy for the use of dynamic route signing (trailblazers) for indicating alternate routes is thus appropriate.

Additionally, the use of low-power HAR can be indicated to the public through the use of blank-out signs. These are particularly useful for surface street traffic approaching freeways.

6.3.3.1 - Typical Applications

Changeable message signs (CMS) can provide dynamic information to motorists regarding a variety of conditions, including:

- Congestion - Changeable message signs can be used to warn motorists of congestion that lies ahead as a result of an incident, bottleneck, or special event. In addition, the CMS can be used to provide warnings when unexpected queuing occurs in areas of restricted sight distance such as around a curve or over a vehicle crest.

- Diversion - Changeable message signs can inform motorists of alternative routes that are available, or that must be taken.

- General Guidance Information - directions, plus ways to obtain additional information through other means (e.g., radio).

- Maintenance and Construction Work Sites - Changeable message signs can be used to warn motorists of lane closures in progress so that they can avoid abrupt lane changes. End of queue warnings and alternative route information can also be provided to motorists approaching work sites.

SIGN TYPE MESSAGE TYPE	FULL-MATRIX (LINES 1, 2 or 3 or Alternating Display)	TRAILBLAZER	BLANK-OUT SIGN
PROBLEM STATEMENT			
Delays or Congestion	Line 1	Not Used	Not Used
Ahead...	Line 1		
On Connecting Route...	Line 1		
Incident (Accident, Road Work, etc.)	Line 1	Not Used	Not Used
Ahead...	Line 1		
On Connecting Route...	Line 1 or 2		
STATUS			
Lanes Closed	Line 2 or 3	Not Used	Not Used
HAR in Operation	Not used for this purpose	Possible depending on sign layout	On when HAR Activated
ROUTE GUIDANCE			
Alternate Route	Line 3, Alt Display	Yes	Not Used

EXHIBIT 6.5

Typical Applications of Changeable Message Signs

6.3.3.2 - Sign Displays

Several different types of changeable message signs have been developed. One is the "blank-out" sign in which a single message can be turned on or off as conditions require. Signs of this type might be applicable to Highway Advisory Radio sites being turned on in advance of a particular segment whenever radio messages are being broadcast If only a few messages are needed at a particular site, then a rotating drum sign – consisting of a three or six-sided prism for each line of the message -- may be applicable. The most flexible type of CMS is the matrix sign, which uses individual pixels (on/off) combined to portray a desired legend. Matrix options include:

- Character Matrix - An individual module for each character (letter). The letter spacing and maximum letter width is fixed.
- Line Matrix - A single matrix for each line. This allows proportional spacing between letters, but limited graphics capability.
- Full Matrix - No built-in divisions between letters or lines. This configuration allows the greatest flexibility in the size and stroke of letters, plus graphic symbols.

Another advantage of full-matrix CMS is the ability to display graphics, thereby further enhancing message readability. Graphics should be kept simple, be easily recognized, and be familiar to motorists. The most useful graphics are those which do not require an accompanying explanation on the sign, such as directional arrows, interstate shield, airplane, and lane reduction (based on the international diamond sign).

Several CMS display technologies are available as described below. The following technologies are summarized in Exhibit 6.6 based on a comparison of visibility, power and maintenance requirements:

- Flip Disk
- Bulb Matrix (Incandescent)
- Fiber Optics
- Light-Emitting Diode (LED)
- Hybrid (Flip/LED, Flip/Fiber)

CRITERIA	SIGN TYPE				
	Flip-Disk	Bulb-Matrix	Fiber Optic	LED Cluster	Hybrid
Visibility Day	Good	Excellent	Excellent	Good	Goad-Excellent
Visibility Night	Fair	Excellent	Excellent	Excellent	Excellent
Power Requirements	Very Low	High	Low	Very Low	Low
Maintenance Required	High	Very High	Low	High	High

EXHIBIT 6.6

EVALUATION OF CMS DISPLAY TECHNOLOGY

Message visibility and legibility under all lighting and weather conditions is the most important attribute of a changeable message sign. The chance that a driver will be confused by a display, or miss a sign altogether, must be minimized Purely reflective signs do not provide the necessary quality or visual conspicuity (i.e., "punch") Accordingly, light-emitting CMS technology – bulb, LED, fiber, hybrid – are being installed in most transportation systems.

As to which of the light-emitting technologies is "best", recent CMS evaluation studies provide somewhat contradictory conclusions. All are very similar in performance with respect to target values and mean legibility distances under various lighting conditions. However, only bulb-matrix has been in operation for a sufficient period of time such that its reliability and life-cycle costs can be determined. However, the newer (LED, fiber, hybrid) technologies offer the opportunity for longer life and reduced maintenance costs, due to the reduced power consumption requirements and longer design life of the light-emitting elements.

6.3.3.3 - Sign Controller and Firmware/Central Software

CMS manufacturers can provide a complete and fully operational sign system. But, the sign controllers, local firmware, central software, and communications interface are generally proprietary. This means that if the agency wishes to expand the sign system, they will essentially be "locked" into the original manufacturer. To avoid this predicament, some systems (e.g., Anaheim, Santa Ana, Los Angeles) are specifying their own sign formats and communications protocol during the design phase. It becomes the sign manufacturer's responsibility to provide a sign and sign controller conforming to these specifications, thereby eliminating any proprietary hardware or software which might tie agency to a specific vendor during future system expansions.

6.3.3.4 - Sign Usage and Operation

The purpose behind changeable message signs is to provide dynamic information regarding existing traffic conditions such that motorists can make intelligent route choices. CMS should not merely be used to convey information that could also be displayed by static signing. Rather, these signs should provide timely and accurate information which reflects the current conditions, and which can be used by the motorists to improve their trip time. Moreover, CMS should not provide trivial information -- telling drivers something they already know. Sign messages themselves should be composed with words that are used in everyday conversation by the motoring public in the geographical location of the system. As an example, some of the wording issues addressed by the INFORM System on Long Island include:

- Use of the word "Delays" rather than "Congestion".
- Descriptions like "CAR FIRE" are not used in that this may make the incident interesting, and motorists might choose to see it instead of diverting.
- Alternating messages are not used.
- Use of Exit numbers instead of mileage to identify geographic location and extent of delays.
- Displaying "NORMAL TRAFFIC AHEAD" when no delays exist between the sign and the next downstream sign

The latter usage is an important issue. In Orange County and Los Angeles, the past policies have been to not display any message on the sign unless something out of the ordinary (e.g., an incident) is in progress The logic of this policy is that when the signs are activated in response to an incident, it will command the motorists attention. One potential problem with this policy is a large number of complaints from motorists that the "signs are broken".

Other systems utilize other forms of "non-event" messages. For example, the system in Toronto displays guidance information (e.g., identifying a particular route for the airport) as their non-event messages. The State of Maryland displays public service safety messages (e.g., USE SEAT BELTS/SIGNAL WHEN CHANGING LANES). The Illinois Tollways do a combination of public safety and date/time messages, as well as construction updates.

6.3.4 - Highway Advisory Radio (HAR)

The HAR is intended to provide more specific traffic information at key locations on an more immediate basis than is possible through traditional commercially broadcast traffic reports.

HAR can utilize either live messages, pre-selected taped messages, or synthesized messages based on information from the Traveler Information Database (TID) It is expected that area HAR systems would ultimately employ an automated Voice Response System (VRS) , a microcomputer-based system which uses TID information as its basis for operation The VRS then develops digitized audio messages for dissemination.

Essentially, Highway Advisory Radio can rely upon either of two technologies for transmission as described below:

6.3.4.1 - 10-Watt Transmission (FCC Licensed1

When properly maintained and installed, lo-watt transmitters have a broadcast radius of approximately 3-miles. Based on the new FCC rules, broadcast on any frequency between 530 KHz and 1710 KHz can be used. However, the FCC rulings have opened up the former dedicated traveler information/HAR frequencies (530 KHz and 1610 KHz) to commercial broadcasting. Therefore, the potential for interference from commercial broadcasters has increased. The 10-watt HAR transmission is omnidirectional. Consequently, several adjoining lo-watt transmission zones may result in interference problems due to radio frequency interference of adjacent transmitters.

6.3.4.2 - Low-Power Transmission

This relatively new technology uses 0.1 watt transmitters (not requiring FCC licensing) interconnected and synchronized to form a zone. The zonal configuration allows relatively linear broadcast zones with 1800 foot spacings between the transmitters. The technology has been tested as part of the Santa Monica Smart Corridor project. An operational test bed is being set up in downtown Los Angeles to evaluate its performance in a high-density urban zone. Based on the most recent test results, low-power zonal transmission offers less interference and a stronger signal when compared with a more conventional lo-watt transmitter. Configuration of several zones allows different messages to be broadcast in each zone. Also transmitters can be adjusted so that there is no overlap between zones.

6.3.4.3 - Other Technologies

In addition to the above, a number of other technologies are available with the capability for broadcast on conventional car radios. One alternative is to have an institutional arrangement with one or more public radio stations similar to an arrangement maintained by the Minnesota Department of Transportation In this arrangement, a station's regular programming may be pre-empted for traffic information. One drawback is that it will be broadcasted region-wide while the information may only involve one or two locations.

A second alternative is the use of "leaky co-ax", a technology where direct buried coaxial cable provides linear coverage. However, this technology has not been widely utilized and direct burial cable poses a number of maintenance problems, particularly involving construction projects in the vicinity of the cable.

Finally, digital voice broadcasts can be accomplished using FM Side Carrier Allocation (SCA) which utilize the "sideband", or space between radio station frequencies. Specially equipped radios can tune in the sideband and receive the clear digital signal.

6.3.4.4 - Operational Implication

For application in Orange County, the use of specific HAR messages for targeted groups of motorists augments the use of the CMS in that the HAR can provide more detail than can be provided on the CMS. However, as with the CMS, it is essential that the messages be timely and relevant, Both elements should be consistent with one another. Ultimately, a significant advantage of TID would be the use of the common database for automated message generation with all traveler information system components. Voice Response Systems, allowing automated voice synthesis from a computerized database, are in use today in Chicago, Illinois, where travel time and congestion information are generated from the regular five-minute system, there, congestion and travel time updates are also generated to the media.

6.3.5 - Highway Advisory Telephone (HAT)

Highway Advisory Telephone (HAT) can provide the public with access to up-to-the-minute traffic conditions compiled in the TID. The traffic conditions, in the form of voice messages, are readily available through any public, private, business, or portable touch-tone phone. No further equipment should be required of the public to use HAT.

As with HAR, there are a number of voice response strategies available. However, unlike HAR, HAT cannot efficiently maintain live Operators. Two other technologies, including tape loops (regularly updated) and synthesized or digitized voice response systems, are technically feasible. However, with the implementation of digital signal processing and the decrease in computer processing costs, telephone information systems can he developed which use digitized speech. These new systems, called Voice-Response Systems (VRS), can handle many simultaneous calls, and provide a real-time interface to the host database. In the TOS application, the TID would provide HAT (as well as HAR and other information elements) with the necessary information on which messages can be developed. This capability to handle data, as well as the ability to monitor and log operations, makes VRS an efficient tool for HAT.

6.3.6 - Radio Data Systems

This technology involves use of digital transmissions along FM side channels to specially equipped audio and/or text receivers. Recently in the Bay Area, one vendor (no longer in existence) developed a hand-held digital receiver unit It receives coded information from a central traffic information site (currently relying on broadcast information and other data), and the user can either select a general traffic report for the Bay Area or, by pressing on a portion of a touch-sensitive map on the surface of the unit, receive localized traffic information. Additional information can be received by pressing a touch-sensitive “button” requesting “MORE”.

The IVHS architecture would, in all likelihood, provide a much more detailed database than currently available for these types of devices, and could encourage increased use of digital receivers. In addition to providing information for hand-held units, digitized information encoded through the proposed TID could also be received by vehicles equipped with special digital radio receivers with text displays. The digital codes would be converted to a digitized voice message and/or a text message to be displayed to the driver.

A key to making this technology viable for in-vehicle use is sending messages which are targeted to specific groups of motorists. These might include commercial vehicle operators (e.g., truckers, intercity buses), as well as private vehicle operators. As the use of this technology by the public is dependent upon making it available, it is proposed that a capability to provide digital encoded data be made available through the IVHS architecture, with the private sector continuing their work in developing receivers to convert the coded data.

6.3.7 - Other Digital Interface Opportunities

6.3.7.1 - Teletext

Transmission of congestion, incident, and advisory information is possible through use of a portion of a commercial television channel's bandwidth called the Vertical Blanking Interval (VBI). The IVHS Architecture can service the increasing teletext audience by providing an output to the World System Teletext (WST) interface through the TID. Depending on geographic locations, messages could be targeted to provide information relevant to specific geographic areas.

6.3.7.2 - Silent Radio

Silent Radio could be accessed through some level of media intertie. As Silent Radio networks basically serve as a clearinghouse of information (much like commercial radio), the intertie would be relatively simple. Text-based information would be the prime candidate for transmission to Silent Radio networks.

6.3.7.3 - Videotext

Videotext essentially provides a dial-up access for personal computer users. It is recommended that within the TID, a separate output be provided for access from computer dial-up users.

There are two possibilities for dial-up access of traffic information. Currently, most dial-up "Bulletin Boards: (i.e., Prodigy) are character-based, and the use of Graphical User Interface for PC-based bulletin boards is in its infancy. Therefore, it may be appropriate to provide both a simple character-based output (text-based information, with possibly simple character-based graphics to indicate congested areas or incident locations), as well as an interactive Windows or Macintosh-based access for GUI communications. The GUI interface would provide the capability of transmitting bit-mapped graphics as well as allowing multiple windows to show different levels of information.

One way to enhance the usefulness of videotext would be to develop a home software package which, through its communications interface, would allow the user to access the IVHS data (including incident and route information) for trip planning and, after the user inputs the origin and destination, the software package could select the best route for the motorist.

6.4 NAVIGATION/GUIDANCE

This functional area addresses in-vehicle system and devices which assist the driver with route planning and route following. While the navigation/guidance function does not necessarily include information on real-time conditions, the more advanced systems typically provide this feature. Three types of components are associated with navigation and guidance:

- Location Tracking
- Display Devices and Operational Software to Correct Digital Data to On-Screen Information and Permit User Interface and Processing of Data
- Infrastructure-to-Vehicle Communications and Data Transmission

The respective approaches and technologies are discussed below.

6.4.1 - Location

In order to provide information that is pertinent to the individual driver, it is necessary to know his/her exact location. Methods used to determine vehicle location are described below. It is noted that these methods also apply to AVL.

6.4.1.1 - Dead Reckoning

Dead reckoning is based on integrating measurements of direction and distance travelled to determine a vehicle's location relative to an initial position, The measurements are made by distance (e.g., speed sensors) and heading sensors (e.g., magnetic compass) on the vehicle. Generally, dead reckoning methods also include correction/updating via map matching or one of the methods described below. Map matching corrects a vehicle's position display by comparing the calculated position with a detailed map of the area Correction typically occurs when the vehicles turns -- for example, a vehicle can only turn at intersections with other roadways or driveways, so the actual position must come at such a location as identified on the maps.

6.4.1.2 - Signpost

Signposts -- consisting of a radio transmitter installed to the side of the roadway, or a loop detector/ferrite loop stick antenna embedded in the radio -- broadcast a location code which is received in the vehicle. The location code and a vehicle identification code are then transmitted to the control center via a vehicle transmitter. Accuracy is dependent on the spacing and frequency of signposts, coupled with dead reckoning/map matching between signposts.

6.4.1.3 - Radio Multi-Lateration

Radio multi-lateration employs a radio transmitter in the vehicle and multiple receivers in fixed locations. Measured parameters, such as the differences in signal arrival times or the horizontal directions of signal arrivals, are used to construct triangles based on time differences or signal arrival angles and the known location of the receiving sites to estimate vehicle location.

6.4.1.4 - Loran C

Loran C uses a hyperbolic trilateration system in which several master and slave radio stations transmit signals a fixed time difference apart This generates a series of intersecting hyperbolic curves, whose intersections determine the geographic location. Loran C accuracy is 300 to 700 feet; although the transmission speed (at 100 KHz frequency) can be affected by weather, thereby affecting accuracy.

6.4.1.5 - Global Positioning Satellite (GPS)

GPS receives microwave radio signals from several satellites, from which it calculates the location based on radio triangulation. Accuracy for civilian-use of GPS is approximately 100 feet; although the high-frequency microwave signals may be blocked by tall buildings and tunnels, resulting in less accuracy.

6.4.2 - Display

Information provided to the driver can include current vehicle position, real-time traffic flow conditions (e.g., areas of congestion, speed limits, travel times) on the driver's route as well as on alternate routes, guidance and route following directions, locations of traveller services (e.g., parking, eating establishments, etc.), or some combination. This in-vehicle information can be communicated in several ways, including:

- Map display - the various items of traveler information may be overlaid on a map display of the region, including the roadway network.
- Text information and messages
- Directional arrows indicating the next action (e.g., turn, change lanes, continue, etc.) that the driver should prepare for, and then execute.

This visual information may be displayed on self-contained CRT or LCD units mounted in the vehicle, or projected onto the windshield as a 2-dimensional holograph (i.e., "Heads-up display") for motorist information while driving. The visual displays may also be augmented with audio messages such as a synthesized voice to give guidance instructions.

6.4.3 - Communications and Data

Transmission of real-time information regarding traffic flow and roadway conditions to the in-vehicle device required an air-path communications medium. Examples are described below:

- VHF/UHF low frequency two-way radios (limited number of users)
- FM Side-Channel Transmission (central-vehicle)
- Infrared Beacons with Radio or direct-channel communications (vehicle-roadway), converted to trunk communications with Central facility.
- Television Spectrum - Vertical Blanking Interval, side-channel communications between allocated broadcast channel frequencies (central-vehicle)
- "INRAD" - Use of loop detectors' conductivity to serve as receivers and transmitters of information to vehicles with special radio receivers. Processing could be possible either through localized processing in field or by using existing two-way communications between field processor (e.g., Type 170 controller) and central site.

Use of infrared beacons was developed in Europe for operation of the Ali-Scout system, now under test in Michigan. INRAD is being demonstrated by Caltrans and Cal Poly University at San Luis Obii as a relatively low-cost vehicle-roadway communications system based on existing loop detector installations.

To service in-vehicle systems, the IVHS architecture should have the capability, through the central TID and appropriate data servers, to output digital data in a format usable by driver information systems. As the quantity of system status data to be transmitted after each sampling interval will likely be enormous, the initial effort should be to transmit data of the most critical importance to the driver. This includes congestion data, incidents, and recommended diversion routes. This information can then be processed by the on-board computer in determining a best route.

Communications between the vehicle and a transportation management system is generally two-way -- that is, not only does the system transmit data on traffic flow conditions to the on-board devices; the equipped vehicles may also transmit data on their individual speeds, travel times, frequency of stopping, etc. to the system for processing. In this manner, the equipped vehicles may function as traffic measurement probes. These probes will be of great assistance in calibrating detection data and derivation of operational Measures of Effectiveness.

6.4.4 - Discussion

Several in-vehicle guidance/navigation systems arc being developed and tested in North America, Europe, and Japan. The major programs in the United States include:

- Pathfinder - A recently-completed cooperative test and evaluation sponsored by FHWA, Caltrans, and General Motors. Pathfinder provided up-to-the-minute traffic congestion information to 25 test vehicles operating along the Santa Monica Freeway Smart Corridor in Los Angeles.

- Travtek - A cooperative effort among FHWA, Florida DOT, General Motors/Hughes, the American Automobile Association and the City of Orlando, Florida; Travtek provides traffic congestion information, optimal route guidance, and motorist services “yellow pages” to one hundred test vehicles (including 75 rental cars) in the Orlando, Florida area. The system uses a built-in touch screen terminal, and receives information via radio from the Orlando freeway traffic management system regarding congestion.

- ADVANCE - A joint venture of FHWA, Illinois DOT, and Motorola Consortium; ADVANCE will provide dynamic in-vehicle navigation and route guidance systems for up to 5,000 test vehicles operating in the Chicago area. These vehicles will also serve as probes supplying real-time information to the traffic management center. The emphasis will be on arterial roadways.

The private sector is the primary force behind the development of in-vehicle guidance/navigation systems in North America. Moreover, as described in the preceding paragraphs, these various on-board systems are quite diverse in terms of the techniques and technologies used. As development and testing efforts continue, some of the alternative approaches will likely be abandoned due to technological limitations, human factor considerations, excessive costs, or some combination. Nevertheless, in the near future, it is essential to develop and issue standards for in-vehicle navigation/guidance systems. Of critical importance will be the development of communications standards -- including network architecture, air-path medium, interface hardware, data rates and protocols, and message contents and formats. Unless such standards are developed and adopted by the private sector, the navigation/guidance function could become a hodgepodge of different and incompatible in-vehicle systems.

In the short term, the Orange County IVHS Architecture will benefit users most through serving County-wide user base. This means that in the short-term, existing standards and communication methods should be utilized. Hence, the Navigation/Guidance functions in the Architecture can be met in the short-term through the use of positive guidance strategies available through changeable message signs (which require no in-vehicle equipment) and through HAR (which requires only a broadcast radio in the vehicle). However, the surveillance functions (including use of AVI and AVL) are to be implemented at a global level as soon as possible, such that the use of in-vehicle devices and related standards developed by the private sector becomes immediately feasible.

6.5 CONTROL STRATEGIES

This functional area includes those management and control strategies needed to improve roadway network efficiency, to manage demand, and to enhance traveler safety, in conjunction with the Countywide goals and objectives. The IVHS Architecture for Orange County can be said to incorporate an "IVHS Network", as defined in Chapter 3, containing the following types of facilities:

- Freeways
- Surface Streets
  "Smart Corridor", Major Arterial routes Parallel to or crossing major freeways within a defined travel corridor

- "Smart Streets", Surface Routes of regional significance which carry high traffic volumes across

- Other Surface Streets - Those major arterials which are of local and regional significance, as well as roadways of local significance for circulation.

- Transit Service
  Buses
  Rail

The emphasis on central in IVHS is related to roadways. Hence, the bus component of Transit Services is considered as a part of the freeway and surface street traffic management, although it is also a unique element in terms of traveler information and public transportation user services. Rail is this not considered in Control Strategies, except where it interfaces with the roadway network. (An excellent example of this is where light rail lines use surface street right-of-way, such as the Metro Biue Line in Downtown Long Beach and along Washington Boulevard in Los Angeles. Light rail must use the same signalized intersections as surface street traffics and thus adaptive and responsive timing strategies are important in reduction of delay.)

6.5.1 - Freeways

Freeway control strategies can be separated into two categories:

- Control of Entry Rate
- Management of Demand on Freeway

Entry control is accomplished through the use of ramp metering, as discussed in more detail below. Management of freeway demand is a broader area, and includes real-time strategies such as ramp metering and route guidance, as well as appropriate traveler information strategies. The use of policies and practices including roadway pricing and toll collection can also contribute to management of freeway operations.

6.51.1 - Ramp Metering

Ramp meters consist of traffic signals on freeway on-ramps. The purpose of ramp metering is to control the rate at which vehicles enter the mainline freeway, such that downstream capacity is not exceeded. In turn, this allows the freeway to increase the volume carried at a higher speed.

Another benefit of ramp metering is its ability to break up platoons of vehicles that have been released from a nearby intersection. The mainline, even when operating near capacity, can accommodate merging vehicles one or two at a time. However, when groups (i.e., queues) of vehicles attempt to force their way into freeway traffic, turbulence and shockwaves are created, causing the mainline flow to breakdown. Reducing the turbulence in merge zones can also lead to a reduction in the sideswipe and rear-end type accidents that are associated with stopand-go, erratic traffic flow.

Ramp metering can serve other purposes, as well, including:

- To discourage drivers from using the freeway for very short trips. Ramp metering is more likely to divert short trips to the arterial streets rather than long trips because the time savings resulting from improved freeway flow will be smaller (or non-existent) for short trips as compared to longer trips.

- To provide incentives for bus ridership and carpooling by allowing HOVs to bypass the ramp meter. Typically, the time savings is one to three minutes.

In essence, ramp metering red&tributes the freeway demand over time -- storing any excess demand on the ramp, instead of on the freeway in the form of stopand-go traffic. While this mode of control is used primarily to reduce the impacts of recurring congestion during peak traffic periods, ramp metering can also be implemented to combat incident-related congestion. For example, meters upstream of the incident area would operate at low metering rates, limiting the number of vehicles entering the freeway. Using surface-street CMS and other driver information devices, entering vehicles would be diverted to on-ramps downstream of the incident. These downstream on-ramps would operate with relaxed metering rates (or no metering) in order to handle the increased demand

In Orange County, the new TOS should provide the capability for providing corridor central ramp metering strategies such as those described above which can react to specific incidents or reesponse plans for multiple sets of ramp meters.

Control modes can range from pre-limed (i.e., fixed release rates based on a preset schedule) to local traffic responsive (i.e., rate is calculated in response to traffic flows for adjoining mainline detectors) to system-wide control, which looks at an entire corridor and provides more equitable metering rates across the corridor. With the latter, this assures that no one meter is unduly restrictive (this mitigates potential queues which back into the surface street).

HOV bypass lanes are used at specific ramps to provide a travel time for use of carpools, vanpools and buses, generally through leaving the bypass lane unmetered. As an alternative, if HOV volumes increase substantially, they can metered also, but at a more favorable rate than for single-occupancy vehicles.

651.2 - Routing Strategies

The management of freeway congestion involves development of a combination of strategies. In particular, major incidents cause a natural diversion of traffic off the freeway system, which in turn creates difficulties for jurisdictions operating the traffic control systems along the surface streets. This is an area which requires an extensive amount of interagency coordination and operations planning activities, such that an appropriate set of responses can be set aside for different types of incidents or for specific events. These proper responses are done on a coordinated basis. As this can be difficult with multiple agencies and with the staffing levels available, real-time building and implementation of response plans requires some degree of automation. This can be done through the use of Expert Systems, which are further discussed in Section 6.7. Such a process is currently underway for the Smart Corridor project in Los Angeles on the Santa Monica Freeway, and will be an important element in both individual Smart Corridor operations and multiple corridor operations (e.g., two corridors operating together) as proposed in the M-IS Network (Chapter 3).

Depending on the nature of an incident or event, and the magnitude of traffic congestion, it may be necessary to implement alternate route plans. Regional diversion is often needed to direct traffic away from the general area of congestion (e.g., as may be caused by an incident), reducing overall traffic demand approaching the site.

Local diversion routes are merely relief valves for congested freeway traffic in the immediate vicinity of the incident site, and cannot be expected to completely solve the congestion problem. However, advanced planning and effective implementation can increase local alternate route capacity, and save many hours of motorist delay. Local diversion routes may be developed for nearly every interchange-to-interchange segment of the freeway network and for all possible directions, including complete closures.

Proper operation of the surface streets is critical to the successful operation of local route diversion. Items which must be addressed include:

- Traveler Information - Travelers must be informed of the desirability or, in the case of a freeway closure, the necessity of diverting. Diversion information can be provided to motorists on the freeway via changeable message signs, highway advisory radio, and media reports as discussed in Chapter 3.

- Motorist Guidance - Once motorists have been diverted from the freeway, it is crucial that they be provided positive guidance throughout the surface street network, directing them back onto the freeway at the appropriate ramp. Trailblazer signs can be installed along the alternate route whenever diversion is implemented A possible sign message for general use would simply read "DETOUR" with an arrow indicating the direction to follow (i.e., right, left, or straight). Velcro backed arrows could be employed to allow a single sign to be used for any direction of travel; and roadway symbols (e.g., Interstate shield, state route) could also be included, The signs may be a fabric or plastic material, with collapsible stands, for installation. These signs may be included in police or transportation agency vehicles; of if a diversion route is frequently used, the signs and stands may be stored in controller cabinets along the route (assuming that space is available). Police officers are often stationed at key intersections. Not only does this provide additional route guidance, but also enhances motorists safety along the diversion route.

- Signal Timing - Whenever diversion routing is implemented, the timing of the signals on the surface streets should be changed to accommodate the new traffic demands.

- Congestion - There is the possibility of "over-diverting", thereby overloading the surface streets. If traveler information sources direct motorists to divert, and drivers find the alternate route is congested, then the reliability and credibility of future information may be questioned by the motorists. Monitoring the traffic flow on the surface streets is therefore an important part of diversion route implementation.

651.3 - Roadwav Demand Pricing

Another form of demand management is roadway pricing, in which motorists are charged for the use of the facility. It is envisioned that any roadway pricing scheme will utilize AVI technology and electronic toll collection as discussed earlier in this Chapter. Instead of standard toll booths -- which cause delay and increase air pollution -- individual vehicles are charged and subsequently billed for their use of the roadway (or some form of prepayment and debit system amy be used) based on the number of miles driven, the origin and destination of their trip, the time-of-day/day-of-week when the trips were made, and where the vehicle was parked. Such information can be readily obtained from widespread application of AVI technology coupled with an appropriate real-time data base. A surcharge might be added to the roadway pricing scheme whenever congestion was predicted to be especially heavy, or during periods when air pollution standards were being exceeded. The surcharges could be established in real-time, and then communicated to the public via the traveler information elements.

There will probably be significant institutional constraints to resolve before roadway pricing can be implemented. The potential "invasion-of-privacy" with AVI has previously been noted. Another issue may involve the equitable treatment of the economically-disadvantaged driver relative to the wealthy driver.

6.51.4 - Congestion Prediction

At present, traffic management systems initiate actions after the roadway has already become congested. In the future, systems might predict when and where congestion will take place, and then implement steps to prevent the predicted congestion from occurring -- for example, informing drivers and soon-to-be-travelers of alternate mutes or alternate modes, advising them to delay trips, diversion, and modifying control strategies such as traffic signal timings and ramp metering rates. Including this "congestion prediction" capability into IVHS-based systems will require research into new traffic assignment and corridor optimization models such that the system can anticipate where congestion will occur, and then evaluate the effects that various strategies will have on travel patterns and corridor operations. AVI and AVL, technology should prove very useful in this regard, by providing current origin-destination data, and providing real-time information for calibrating the optimization models and for evaluating the effectiveness of the resulting traffic management strategies.

6.5.1.5 - Freeway Incident Management

Non-recurrent congestion has a significant impact on overall traffic flows, as it accounts for more than half (approximately 52%) of all traffic congestion Incident management addresses a number of different methods to respond to and clear incidents, as well as reduce incident-related congestion. Incidents addressed may include:

- Accidents
- Disabled Vehicles
- Spilled Loads
- Adverse Weather or Natural Disaster
- Special Events
- Construction and Maintenance

Due to increased side friction, weaving to avoid the blocked lane(s), and rubber-necking, the impact of an incident on roadway capacity goes well beyond the simple subtraction of the number of blocked lane(s). The capacity reduction effect for various freeway cross-sections and incident configurations is shown below in Exhibit 6.7.

Exhibit 6.8 illustrates the impacts of lane-blockage duration on queue length.

Incident management can be defined as a coordinated preplanned use of human and mechanical resources to restore full capacity as soon as possible after an incident occurs, and to efficiently manage traffic during the incident The following activities are required:

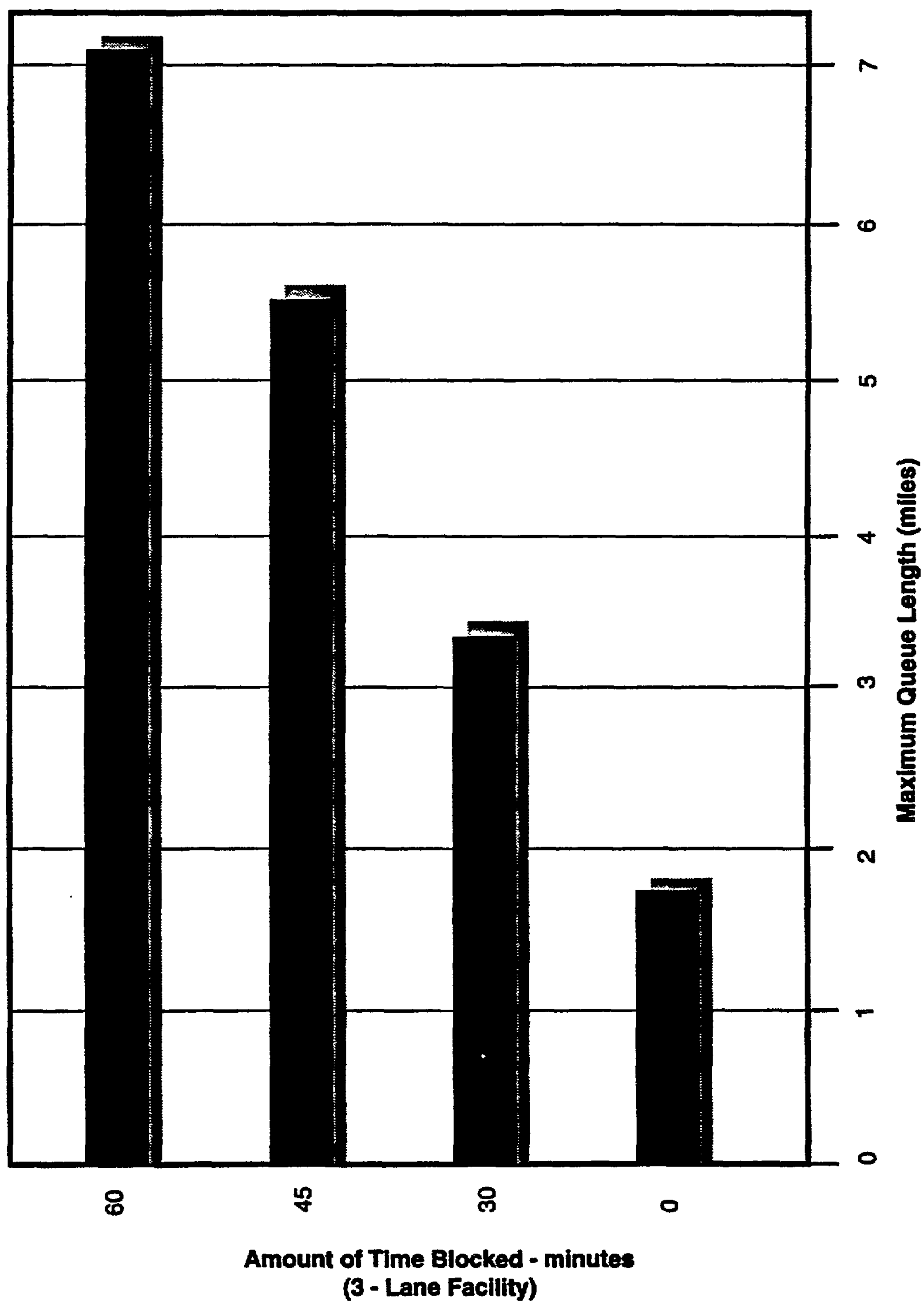
- Reducing the time required to detect the occurrence of an incident (i.e., awareness)
- Reducing the time required to verify the incident, identify the types of vehicles involved, and to determine the proper response (i.e., identification)

Exhibit 6.7 CAPACITY REDUCTIONS DUE TO INCIDENTS

	FREEWAY CROSS-SECTION (No. of Lanes)			
Blockage	2	3	4	5
Shoulder[1]	20%	17%	15%	10%
l-Lane	65%	47%	42%	33%
2-Lanes	---	7 %	67%	55%

This does not include vehicles merely parked on the shoulder

Exhibit 6.8
Queue Length as a Function of Incident Time



jhk & associates

Transit IVHS / Transit 2.1 / Queue Length as a Function

- Reducing the time required to notify the necessary agencies and organizations, and then for the appropriate equipment and personnel to arrive on the scene (i.e., response)

- Reducing the time required for the incident to be cleared from the roadway (i.e., restore full capacity), while exercising proper on-scene management of traffic flow (i.e., clearance)

- Providing traveler information throughout the process.

Exhibit 6.9 illustrates how various optional strategies can be applied to management of non-recurrent congestion, and shows how these can reduce roadway demand and roadway delay. The means to alleviate congestion caused by incidents include the following:

Accident Investigation Sites (AIS)

An AIS provides an area in which parties involved in an accident can relocate to or be relocated, away from the view of mainline traffic. All police or insurance investigation activities can be conducted at this site, which would also include an emergency call box for dispatch of police or emergency crews. This area requires construction of an appropriate parking facility with physical shielding from freeway view, but with adequate lighting and the call box present such that the safety of the parties is enhanced.

Public Information Campaign

Such a campaign would encourage motorists involved in accidents in lane to either move vehicles to the shoulder or, where available, to Accident Invesigation Sites. Where this is not possible, motorists should be encouraged to stay in their vehicles (with flashers on) until the arrival of a roving Freeway Service Patrol vehicle. The use of cellular call-in capabilities to CHP should also be promoted, either through Call Boxes or via in-vehicle or personal cellular phones.

Example 6.9
COMPARISON OF CONGESTION MANAGEMENT STRATEGIES FOR NON-RECURRENT CONGESTION

Case	Description	Radio Traffic Report:	Incident Response Team	Portable CMS/ CHP Upstream as incident	Remote Detection/ Evaluation	Coordinated Central CMS/Response Strategies	Demand Reduction	Delay Reduction
1	No Active Management						22%	0%*
2	Incident Management Only						22%	9%
3	Limited On-Site Traffic Management						33%	33%
4	Centrally-Monitored Traffic Management						60%	63%

* Base condition. All delay reductions compare with this base condition.

Freeway Service Patrols (FSP)

OCTA, Caltrans and CHP jointly operate an FSP service in Orange County along 60 miles of freeway. The FSP currently consists of 15 tow trucks and two contracted tow truck operators that patrol the freeway network, providing motorist assistance and handling minor incidents. The FSP addresses many of the incident management elements. The time required to detect an incident may be reduced in some cases -- the number of incidents affected and the time savings being dependent upon the frequency of the service patrols. Incident verification may also be enhanced because of the direct contact in the field. Most importantly, freeway service patrols can dramatically reduce the incident response and clearance time because the service provider is immediately on the scene, rather than appearing several minutes (or longer) after the initial call has been placed.

Freeway service patrols have proven to be one of the most effective strategies for reducing the delay and secondary accidents associated with incident-induced congestion. While the investment in equipment, materials, and labor can be significant, the services and time savings to motorists usually far exceeds these costs. For example:

- A study on the Chicago "Minuteman" service indicated a benefit-cost ratio of 17:l. Another study of a freeway service patrol in 1989 on the Santa Monica Freeway in Los Angeles resulted in a 15:1 benefit cost ratio. The more recent full-scale FSP deployment in Los Angeles County has resulted in substantial reductions in incident response time.

- Service patrols were initiated along I-95 in South Florida as part of a major roadway widening. Data collected by FDOT indicated that the patrols resulted in a significant decrease in incident duration time (for those incidents to which they have responded) from approximately 60 minutes to about 20 minutes.

- The rapid removal of incidents and debris from the freeway travel lanes before they can cause secondary accidents is undoubtedly another benefit -- albeit a difficult one to quantify -- associated with service patrols.

Perhaps the most telling evidence regarding the value of freeway service patrols is the multitude of letters, cards, and notes of appreciation that are received each year by the operating/sponsoring agencies from motorists who have been assisted. In essence, FSP is also a very effective public relations tool from the perspective of the operating agencies.

6.5.2 - Surface Streets

Vehicle movements on the surface street network are controlled by adjusting signal timing. Signals between adjacent intersections, on parallel roadways, or throughout an entire network may be controlled and coordinated by a system such that the traffic moves with minimal delay and stops. Computerized traffic signal control systems can be classified in terms of their processing features and their levels of adaptive control as summarized below.

6.52.1 -Types of Signal Systems

In general, the most predominant type of signal systems in Orange County today are centralized (either UTCS or vendor-specific) or closed-loop distributed systems (again, vendor-specific). However, development of microprocessor-based signal system components both for central and field elements will likely result in additional changes to signal system operators and configurations. The nature of the IVHS Architecture will be to accommodate all types of signal systems. To do this, however, the appropriate data for signal status and traffic flow used for signal system operations must be made available to the information network. The methodology for doing this is described in Chapter 7.

6.52.2 - Adaptive Control

The control strategies associated with most computerized traffic signal systems -- including the aforementioned closed-loop and UTCS systems -- are referred to as First Generation Control (1 GC). Under 1 GC, several signal timing plans are developed by traffic engineering personnel, and the resulting signal timing parameters (i.e., plan number, cycle length, split, offset, etc.) are then manually converted to the proper format and entered into the system's data base for subsequent selection and implementation. Timing plans may be selected by system operators ("manual"), or a Time-of-Day/Day-of-Week (TOD/DOW) basis, or using a traffic responsive algorithm. With traffic responsive selection, the system selects the prestored timing plan whose "signature data" -- volume and/or occupancy parameters for each system detector -- best matches the current traffic flow conditions as measured by the system detectors.

A more advanced control strategy, referred to as Second Generation Control (2 GC) has also been developed. Under 2 GC, the timing plans are developed by the system through the use of traffic volume and occupancy data acquired from system detectors, and the timing parameters are automatically developed and implemented by the system. The advantage of this strategy over 1 GC is a significant reduction in the labor required to collect data, develop signal timing plans, and input data into the computer. A major disadvantage (as is the case with all advanced control strategies) is the need for increased detectorization. Moreover, no mechanism is provided for these timing plans, newly developed by a computer model, to be analyzed by traffic engineering personnel before they are implemented -- a situation that can lead to unpredictable results on the street.

A compromise between 1 GC and 2 GC has been developed and is known as 1.5 Generation Control (1.5GC), which is being implemented for the City of Anaheim, and has already been implemented in Los Angeles. With 1.5 GC, signal timing plans are developed automatically by the TRANSYT-7F (or similar) program using current traffic flow data collected by system detectors and some manually entered traffic flow parameters such as turning movement percentages.However, the plans are not implemented until they have undergone an engineering assessment, and a determination has been made that the new plans are superior to the old ones. This strategy offers the labor saving advantages of 2 GC, but retains the feature of 1 GC implementing preplanned and more predictable signal timing plans.

Fully adaptive control (i.e., 3 GC) creates fully responsive, on-line traffic control systems. An example of a 3 GC strategy is SCOOT (Split, Cycle, and Offset Optimization Technique), developed by the U.K. Transport and Road Research Laboratory. SCOOT is demand-responsive and adjusts the cycle time, phase splits and offsets in accordance with an on-line optimization process. Short term demand fluctuation information supplied by vehicle detectors in advance of each intersection is input to a traffic model. The model predicts the total delay and stops caused by the signal timings, and a signal optimizer adjusts the timings to minimii delay and number of stops. SCOOT operates small groups of intersections on a common cycle length and makes frequent, small modifications to the signal timings according to short term demand fluctuations.

IVHS Operational Tests are underway using SCOOT in the City of Anaheim as well as in Irvine.

Future traffic signal control systems may utilize a fourth generation control strategy. In addition to providing a quicker response to rapid changes in traffic flow conditions, 4 GC systems may also perform short-term forecasting, based initially on historical experience, and ultimately on real-time origin-destination estimation.

6.5.2.3 - Pre-emption

Another signal system related control strategy is preemption. The philosophy of signal preemption is to increase safety and/or efficiency through providing a more controllable traffic operation. Without preemption, a vehicle requiring emergency priority travels through the signalized intersection regardless of signal indication, and is fully dependent on vehicles along the route and on the cross-street moving out of the traveled way and stopping.

Preemption results in signal indications which provide or extend a clear path (i.e., green indication) for the priority vehicle, thereby enforcing the clearance of cross street traffic from the vehicle's path. This positive form of control by nature increases safety, as well as reducing the delay to an emergency vehicle in waiting for traffic to clear an intersection. The reduction in response times, and conversely the potential to save human lives as well as property, is a benefit which has convinced many communities to invest in preemption. At the same time, signal preemption interrupts a signal cycle, and consequently may increase overall vehicle delay. Signal preemption may also be applied to bus operations to reduce transit delays.

As discussed in Chapter 4, the use of regional (Cross-boundary) pre-emption is currently a controversial subject in Grange County. The consensus is that more work needs to be done in evaluating the overall vehicle delay impacts of regional preemption strategies and ascertain how there can be integrated with signal system operations in order to mitigate this overall delay.

6.6 IN-VEHICLE SENSORS

In-vehicle sensors generally can be performed to as the vehicle-based, or autonomous, components of Automated Vehicle Control Systems (AVCS). Examples of these technologies are presented below. While most of these generally are vehicle-specific, the use of information from the IVHS network may be appropriate for elements such as adaptive cruise control (the setting of appropriate cruise speeds given travel conditions on the network). Likewise, certain devices such as MAYDAY sensors require an immediate communications capability with a central monitoring facility for response.

The purpose of AVCS is twofold One purpose is to improve motorist safety by enhancing the driver's perception and control of the vehicle, thus avoiding accidents. The second purpose of AVCS is to improve transportation efficiency. This can be done by enhancing roadway capacity through enabling closer vehicle headways and eliminating speed differentials between vehicles traveling in the same lane. Additionally, in combination with future guideway and motive technologies, it should eventually be possible to increase travel speeds while at the same time, enhancing safety and emissions, while reducing fuel consumption.

For vehicle-based AVCS components, electronic systems can provide warning and/or control functions. A warning system may alert the driver of an impending collision or roadway condition so that the driver may take corrective action. A control system may automatically brake or steer the car to avoid the accident. These systems would be developed as components of the automobile itself, and integrated into the vehicle as safety or operational features.

Infrastructure-based systems are technologically farther into the future, and would rely more on enhancements to the roadway itself for information and control. These systems can allow more efficient control of the traffic, potentially increasing roadway throughput by a factor of two or three or more. An example of this type of system is a limited-access automated lane in which all vehicles are automatically controlled ("platooning").

The elements of AVCS will require a significant amount of development, As they become available, vehicle-based systems may be expensive and in all likelihood not capable of retrofit to older vehicles. Typical features of these systems would be cruise control adaptive to observed surrounding traffic flows, automatic braking systems, vision enhancement systems, and near-obstacle detection radar. However, issues of driver trust of the automated systems must be resolved, as well as liability issues if accidents occur involving a vehicle under some form of automatic control.

6.6.1 - Current State-of-the-Art

Some of the enabling technologies for in-vehicle sensors have been under development over the last 30 years, and are available on automobiles now. Examples are anti-lock brakes, traction control, active suspension and four-wheel steering. The European PROMETHEUS program has included demonstrations of autonomous intelligent cruise control, vision enhancement, proper vehicle operation, collision avoidance, cooperative driving, and emergency warning and calling; extensive field tests are planned beginning in 1994. Japan is planning a fully-automated truck lane between Tokyo and Osaka. Volkswagen has demonstrated a form of automated platooning and parking technologies.

6.6.2 - Current Activities

Most of the activity in AVCS currently involves research. The Texas Transportation Institute at Texas A & M University has ongoing studies in, among other elements, real-time visual control for intelligent vehicle and platooning. The University of California PATH Program is researching lateral guidance of vehicles using magnetic fields generated from roadway implanted permanent magnets and longitudinal control. At Cal State Sacramento, a broad-based exploration of infrared, visible, and microwave radar guidance for lateral control of vehicles is underway. The IRVW-Futura, Volkswagen's research car, uses an infrared laser to sense the distance from the car ahead and then use that data along with speed information to inform the driver if the distance is less than acceptable for the car to stop safely. It also combines the laser sensor with ultrasonic sensors and four-wheel steering to allow the car to park itself automatically. There may be vehicle fleets with longitudinal systems (e.g. early warning collision) as early as 1993. Platooning of multiple vehicles into tightly spaced convoys is also being researched and promises major capacity gains. PATH is currently running experiments of four-vehicle platoons whose spacing and closure notes are measured by radar and sent by RF communications to all vehicles. This information is then used to control the throttle, while the driver steers. They are planning experimentation on entry and exit for platoons in 1993.

6.6.3 - Future Developments

Perhaps more than any other element of IVHS, AVCS holds the most potential for changing the basic structure of transportation systems through the use of electronics and other technologies. However, as discussed above, such potential will be realized over a much longer term than with other IVHS technologies. Exhibit 6.10 presents the likely implementation process for AVCS technologies, specifically, in-vehicle sensors. In general, these vehicle-based warning systems will be the first AVCS technologies utilized. These will be complemented in the future by increasing levels of vehicle control and finally, of infrastructure improvements supporting automated highway operations.

6.6.4 - Capabilities of In-Vehicle Sensors

The capabilities provided by in-vehicle sensors, in order of level of automated control, are warning, vision enhancement, longitudinal or lateral assistance, and longitudinal or lateral control.

This requires a broad range of technologies for detecting a variety of situations, assessing the situation, alerting or assisting the driver and/or controlling the vehicle.

6.6.5 - Issues in AVCS Development

Deployment of AVCS is contingent upon the successful application and reliability of both the communications links and the control components, both from the system infrastructure (i.e., traffic management system) and from the software and hardware measured for in-vehicle sensors. Therefore, the successful implementation of both Traffic Management and Traveler Information elements will be a precursor to many of the eventual automatic control functions that will be implemented. The key function, as with Navigation and Guidance components, will be with vehicle-roadway communications.

EXHIBIT 6.10

FUTURE AVCS DEVELOPMENTS

Category	Near-Term (1992-l 996)	Mid-Term (1997-2001)	Long -Term (2002-20011)
TECHNOLOGIES IMPLEMENTED	Roadway/environment safety systems Silent Alarms Near-obstacle warning Vehicle performance monitoring	Automated highway demonstration "Mayday' capability Passenger Security alarms Perceptual enhancement systems Vehicle/driver monitoring systems Intelligent Cruise control Collision Warning	Collision avoidance systems Automated freeway lanes
SYSTEMS UNDER TEST	Backup warning Adaptive cruise contol Traction (ice) warning and conrol Vehicle performance monitoring Longitudinal collision warning Lane change and merge warnings	Lane and road departure warning Lateral (steering) control Side collision warning Automatic lane change system automatic collision avoidance More advanced vision enhancement Short-headway vehicle following control Rural intersection hazard warning Head-on collision warning	
SYSTEMS TO BE DEPLOYED	Stand-alone, electonic control systems (anti-lock braking, electronic engine and transmission controls, and traction control under acceleration) Simple vehicle performance monitoring Warning systems for side and rear obstacles	Warning systems for frontal collision lane departure, lane change and merge, and roadway conditions Electronic control systems for brake application and steering Vehicle performance monitoring (tire condition, traction, braking, etc.) Adaptive cruise contol Automatic collision avoidance braking Vision enhancement for night, rain, fog	Warning systems for intersection hazards Cooperative Collision avoidance Automated vehicle operation on specially equipped roadways
PRODUCTS			
Electronic longitudinal control	Traction under braking, engine speed, transmission, traction under acceleration	Adaptive cruise contol Automatic collision avoidance braking	
Obstacle/longitudinal warnings	Near Obstacle	Far Obstacle, roadway conditions, reduced traction	Cooperative frontal collision Intersection hazard
Vision enhancement		CCD backup camera w/image processing night vision, fog, rain enhancements	
Lateral warning	Side obstacle	Lane departure, change, merge	Cooperative lane change/merge
Lateral control		Electronic control of steering	
Monitoring of vehicle performance	Tire inflation and reduced traction	Tire condition, traction, braking capability, acceleration capability	Increased capability at reduced cost

6.7 DATA PROCESSING

This section reviews the following areas of information processing and discusses the functional requirements as well as potential solutions.

- Database/Geographic Information Systems
- Networking
- Open Systems and User Interface
- Decision Support

In IVHS, the variety of operational components require a number of stand-alone subsystems. The technology of traffic management has moved in recent years toward distribution of intelligence between central and field hardware elements through the use of microprocessors. From a central operation viewpoint, a potential problem is the need to control and monitor different elements simultaneously. The monitoring of dedicated subsystems on a simultaneous basis is a labor-intensive task if separate terminals are required. Likewise, the development of integrated traffic management strategies requires the use of some means to simultaneously operate multiple subsystems.

6.7.1 - Databases/Geographic Information Systems

For a dynamic operational IVHS database in Orange County, the following functions will be required:

- Collection of data from many systems
- Dissemination of data to many systems
- Access to data from multiple agencies and the public
- Ability to transmit information to in-vehicle devices via appropriate data servers

Two types of database structures can be considered:

- Record-based structure - Deals with elements as quantities and records.

- Geographic-based structure - Looks at elements utilizing spatial relationships Records and characteristics are defined as a function of location coordinates on a particular surface.

The nature of transportation information is that it is spatial in nature. Even typical character-based applications such as signal timing software assess characteristics such as link lengths (distance between intersections), although this information is shown as a simple data record associated with another data record For relatively simple processes that access specific devices for control purposes, it is not necessary to consider such elements as geometric layout and location, as field locations may be reduced to simple identification codes.

However, when accessing a multitude of data and information ranging from traffic conditions for specific locations to status for specific field devices, the multiplicity of information requirements indicate the need to show these items in some graphical sense. Spatial considerations are fundamental to most transportation activities. A transportation system can be modeled as nodes, links, and attributes in a two or three dimensional space. Events occur within the framework of this model at a node (an accident, a signal location), along a link (vehicle volumes, available capacity), or within a buffer of the link (e.g., number of people living within 250 feet of a highway). Historically, such data has been incorporated into multiple information systems essentially unrelated to one another[1].

With development of Geographic Information Systems (GIS), the various static data and dynamic information can be treated as information layers for specific spatial coordinates. A GIS may range from a simple two-dimensional display (bit-mapped graphics) all the way to a topological GIS which allows graphical displays based on actual topography, and which have several different layers of information, plus the capability for complex data analysis along the network. The nature of such a system for IVHS is that most of the data to be processed will be of a real-time nature.

On the simplest level, this involves display of one or more parameters graphically, as is required to show real-time traffic status on a map using defined color codes. On a higher level, it involves analyzing a series of data (i.e., estimating travel times between two points selected

Sirnkowitz, Howard J., "geographic Information Systems: An Important Technology for Transportation Planning and Operations". 68th Annual Meeting of the Transportation Research Board, Washington. DC, January. 1989 on the map.) At its most complex, the GIS could have the capability of comparing multiple sets of data meeting various constraints, and then selecting a "path of least resistance" along with associated strategies for implementation. Roughly translated, a series of real-time information could be used by a GIS-based Expert System to select an appropriate incident or congestion response strategy.

For any IVHS architecture with some method of central dissemination or monitoring, a GIS database (often referred to as a Geobase) is recommended as the central collection and dissemination mechanism, with other systems (i.e., Expert Systems, control subsystems) accessing the information and performing spatial comparisons. The GIS, through its spatial layering technology, allows viewers to collect and categorize travel information, interpret and analyze the information, aid in problem resolution, and integrate spatially related data from other agencies for interagency analysis purposes[2].

Multiple organizations could have access to the central GIS through a "base map" by which updates can be incorporated and entered into the system. Research on applying GIS to dynamic vehicle routing and control is currently underway. The process of flow optimization and routing requires a spatial sorting of traffic-related data across multiple highway and road network paths. Insignares and Terry[3] refer to several important benefits of a GIS to Advanced Traffic Management Systems (ATMS):

- User can query ATMS in a spatial manner
- Geographically organized information can be shared between agencies, aiding interagency analysis of transportation
- Facilities management functions incorporated into an ATMS can facilitate the management of remote ATMS components.

The GIS must be capable of spatial and temporal (time-comparison) analysis of real-time data in order to predict traffic flow information in conjunction with developing routing and response strategies, as well as navigation and control processing.

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2 Insignares, Manuel and Douglas Terry. "Geographical Information Systems in Traffic Control". Proceedings of the 1991 Annual Conference of the URSIA, Volume 1; San Francisco, CA; August, 1991

3 Insignares and Terry

Exhibit 6.11 presents nine basic functions for GIS[4], as modified for use as part of an ATMS. Three of these functions, Route and Flow Optimization, Route Selection and Navigation, and Tracking and Monitoring, are obvious processing functions applicable to an ATMS, particularly for the Smart Corridor-type applications that require the use of decision support through an Expert System.

6.7.2 - Networking

The interagency nature of a Countywide IVHS Architecture calls for the coordination of operational strategies and providing information from multiple sources which can then be disseminated using common formats. The following are possible data exchange scenarios and dissemination functions in the IVHS Architecture:

- Sharing of data and video images between adjoining local Traffic Management Centers (TMCs) with common areas requiring coordination of signal timing or operational strategies to handle recurring congestion.

- Sharing of data and video between a local TMC and the Caltrans Traffic Operations Center (TOC) for coordination of freeway and surface street operations strategies in response to recurrent congestion or frequent event traffic.

- Correlation of data from various sources and dissemination via various methods, including media links, direct display via cable TV or public kiosks, links to in-vehicle displays.

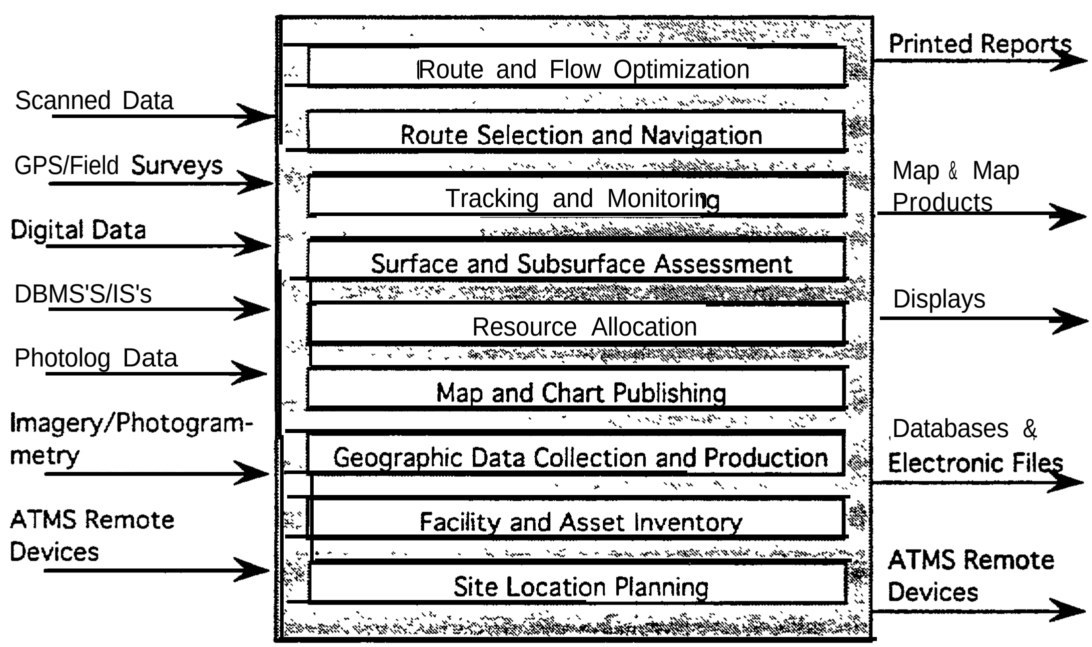
- Correlation of data for dynamic development or selection of multi-agency response plans, including alternate t-outings.

Three types of links are possible for an interconnected M-IS Architecture:

- Direct agency-to-agency intertie (dedicated)
- Dedicated tie-in from all agencies to central data clearinghouse
- Dial-Up connections to any element in the system

4 Hanigan, Francis L: "GIS Marketing in the 1990's". ARC News, Volume 12, Number 1, Winter. 1990

Exhibit 6.11
Basic GIS Functions in an ATMS Application



For continuous operation of system elements, dedicated links are recommended, with dial-up used by system users or interested parties when necessary to access specific information.

Operation of the IVHS Architecture requires the use of networking strategies to provide full access between system elements, including the ability to share resources (e.g., local agency utilizing information from a Caltrans CCTV camera), as well as the ability to access data from other systems. The nature of network structure is that digital communications between devices is accomplished based on standard protocols. A full countywide system with standard interfaces between all elements is a Wide-Area Network (WAN), while a system at the local level with different elements using a standard interface is a Local Area Network (LAN). A typical network interface configuration for LAN's and WAN's is EtherNet.

Likewise, the latest trends in the area of "stand-alone" agency operations (within a TMC or TOC) have been moving toward distribution of processing capabilities. In the past, typical hardware restrictions have come about due to incompatibility and lack of external communications links between existing systems, as well as limitations on memory and size of systems which perform fully centralized control and processing (i.e., the field controller is there only as a back-up, and its operations are controlled on a second-by-second basis by the central computer.) Section 6.7.3 provides an in-depth discussion of open system design concepts, which allow for compatibility of operations across different platforms.

Separate subsystems (e.g., CMS, CCTV, signal system) are responsible for communication to microprocessors in the field (such as Type 170 controllers). The microprocessors themselves have some level of intelligence, including storage of messages, automatic dimming capability and the ability of displaying a message either upon the command of the subsystem computer or based on a traffic-responsive algorithm located at the controller itself.

The interface between different subsystems is accomplished by using a LAN, which utilizes a standard protocol (e.g., serial, Ethernet) for communications between devices.

Chapter 7 provides more specific detail on the agency-to-agency communications link requirements, as defined by the selected architecture. To summarize, however, the concepts of local area networks and wide area networks allows for maximum flexibility and distribution of processing, and thus allows operations to be less restricted by the hardware configuration.

6.7.3 - Open System Design Considerations

The systems designed to service the Orange County IVHS Network must take full advantage of the latest software design techniques. Given the necessary functional requirements, the software design is to allow for a maximum level of flexibility and expandability. This will allow expansion of the system configuration to encompass additional elements over the next 20 years.

The nature of any multi-agency effort is that a variety of hardware and software platforms will be involved. Many systems already exist and must be integrated into a unified system. Since many of these systems evolved independently, each has its own special features and characteristics. With future expansion, more diversity may be added to the system, as different platforms may prove to be more appropriate or cost effective for various tasks., It is thus very reasonable to expect the IVHS network to be very heterogeneous, possibly including hardware from such vendors as Digital Equipment Corporation, IBM, Sun, and a variety of PC makers. Operating systems may include VMS, UNIX, DOS, MS-Windows, and OS/2, as well as others. It is essential that all of the IVHS system software be designed specifically for an Open System Environment (OSE).

6.7.3.1 - Open Systems: An Overview

International standards are currently under development to support software development in an Open System Environment. Many of these standards are being developed under the banner of the IEEE portable operating system interface (Posix) environment. The Posix Open System Environment (OSE) is a set of standards which is being assembled by Working Group 1003.0 of the IEEE Technical Committee on Operating Systems (TCOS). The Posix OSE standards include both IEEE Posix standards as well as standards from ANSI and ISO.

The Posix OSE standards define two types of standard interfaces: the Application Program Interface (API) and the External Environment Interface (EEI). APIs are procedure calls made to the platform on which an application is running. These calls may interact with the operating system, system utilities, or other applications. In an IVHS Network, these calls might include database transactions and file transactions. EEIs are connected to the external environment, which is often defined to include external devices such as printers, graphical displays, disks, and networks. In the IVHS Network environment, the external environment will also include controllers, detectors, changeable message signs, CCTV cameras, and other hardware. As integrated multi-agency elements, including Smart Corridor systems, are developed, the use of the Posix Open Systems Architecture model (illustrated in Exhibit 6.12) is essential.

The Posix OSE standards address four general areas of service: system services, communication services, information services, and human-computer interaction services. Details of these areas will be discussed below in the Issues section, where the implications of each area on system design is examined. The goal of the Posix Open System Architecture is to isolate the application from the peculiarities of the underlying operating system, as diagramed in Exhibit 6.12. The layered approach allows the introduction of software packages that are specific to the system or application, such as would be required in the IVHS Network. When considering the OSE architecture, though, it is important to note that many of the specifications are under development. Compromises will be required in order to proceed with implementation in the current environment.

An excellent example of compromise is seen in the network communications area. Exhibit 6.13 shows the reference model for Open Systems Interconnection (OSI) and the currently available interfaces for network communications. The lower level interfaces provide very little abstraction from the details of communications and contain the most system-specific code. NetBIOS is at the Session Layer, IPX is at the network layer, and SPX is at the session layer. Sockets, while existing at the session layer, provide a little more abstraction than the previous three interfaces, and thus lies a bit closer to the application layer. NetBIOS, SPX, and IPX were all spawned from the PC environment and find the most support in that area. Sockets were born in the UNIX environment and have been implemented across virtually all platforms.

In an ideal world, the programming interfaces available at the application layer could be used exclusively. This would allow maximal abstraction and isolation from transport protocol and operating system idiosyncrasies. Unfortunately, none of these interfaces is supported across a wide range of platforms. Named Pipes may only be created in the OS/2 and UNIX environments. The Transport Layer Interface (TLI) has the advantage that it may operate on either TCP/IP, STREAMS-based, or other transport protocols. It is mostly used in the UNIX

Exhibit 6.12
Posix Open System Architecture

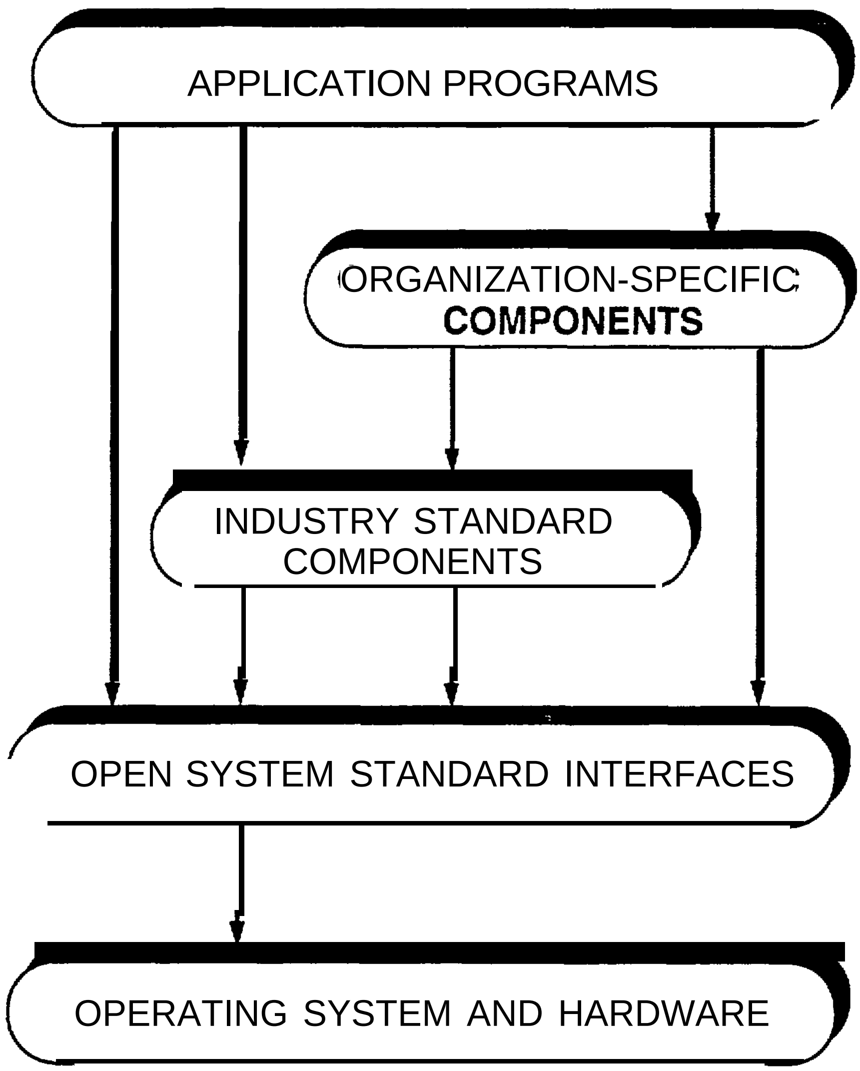
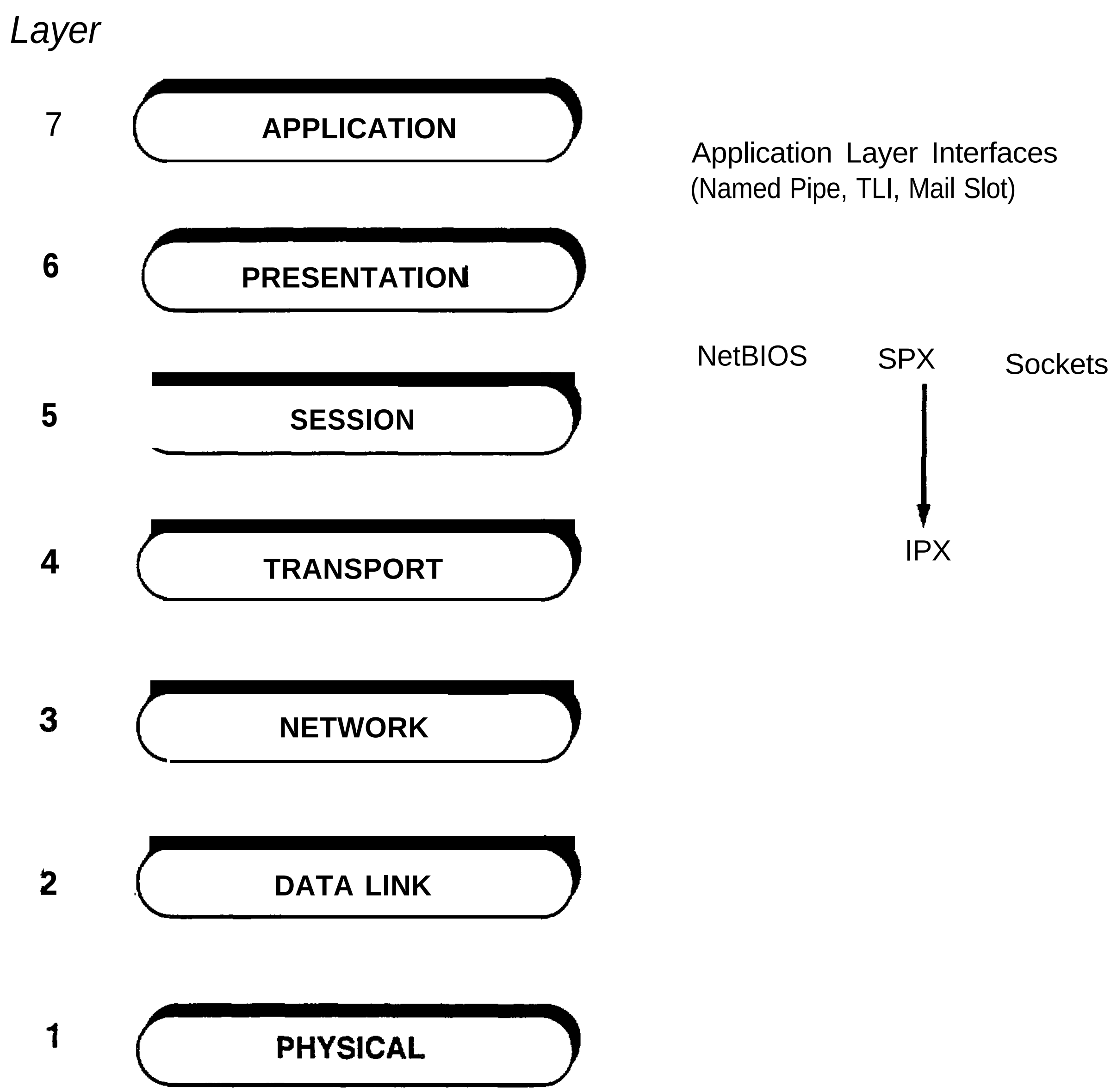


Exhibit 6.13
Reference Model for Open Interconnection (OSI)



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environment and support on other platforms is limited. Mail Slots originated from the Microsoft LAN Manager, and only servers running OS/2 or UNIX can receive messages. The most widely supported communication mechanism of those mentioned above is the TCP/IP Socket.

Accordingly, despite the undesirably low level of the interface, it must be the mechanism of choice in the current development environment Furthermore, its widespread use ensures that it will be supported as a more suitable interface is developed in the future.

Another organization which should be considered in the Open Systems area is the Open Software Foundation (OSF). They have developed the Distributed Computing Environment (DCE) which addressed four problems: 1) the diversity of operating environments, 2) the large number of interconnected systems, 3) security, and 4) the need to create new network applications. DCE is compliant with OSI and Posix standards and specifies interfaces and protocols for a network computing environment. The networking facilities, for example, will operate over many network protocols and will handle the bit and byte ordering tasks that are a part of data conversion between hardware platforms. DCE is also gaining support from major software vendors, and DCS will be available as a part of the operating system software under UNIX, VMS, MVS, MS-Windows, and others. OSF is also the source of OSF/Motif, which has become the dominant toolkit for X Window based graphical user interface development.

Some of the major benefits of moving toward an Open Systems environment may be summarized as development and maintenance philosophies. By identifying and adopting the appropriate sets of standards, a wide variety of tools will become available in the long term. This will accelerate application development, since tools may be purchased rather than developed This is the "Buy, not Build" philosophy of development. Furthermore, the use of purchased tools moves the majority of maintenance from the developer to the vendor. The developer is then responsible only for maintenance of the application, not of the tools upon which the application was built.

6.7.3.2 - Open System Design Issues

Issue 1 - Open Svstem Environment: System Services

Software developed specifically for the Orange County IVHS Network should be portable across operating systems and compilers. A variety of other operating systems may be used at the TOC, TMC's and other system facilities.

The System Services category includes facilities provided by the programming language and the operating system. Standards are already in wide use in the area of programming languages. An example is the ANSI standard for the C Programming Language (X3.159-1989). Many C compilers now support "ANSI C". For other languages, specifications exist, which describe the features of the language. The C++ language is described by specifications created by AT&T, the originator of the language. Many compilers support the AT&T version 2.0 specification, and some support the version 2.1 specification. In this case, it will be necessary to identify the minimum desired level of functionality and the corresponding specification, and identify compilers which are compliant with that specification It will be necessary to identify appropriate compilers across a variety of platforms.

In the arena of operating system functions, the Posix kernel standard (1003.1) specifies language bindings for C. Similar bindings for Ada and Fortran will soon be available, and a set of language independent bindings are under development by Posix working groups. These binding specifications provide a common interface to operating system functions such as file input and output and process control. Thus, the use of such functions should be portable across a variety of operating systems.

Posix support is becoming available from many of the major computer hardware and software vendors, including IBM, Digital, Sun, AT&T, and MicroSoft. It should be feasible to direct software development to adhere to the Posix kernel standards. Since the C++ language provides C language binding facilities, these facilities may also be utilized in the C++ environment.

Software for the IVHS Network should be developed using the Posix standard kernel interface to ensure portability across platforms. The language of choice is C++, and a uniform set of compilers need to be identified for a variety of environments

Issue 2 - Open Svstem Environment: Communication Services

In a distributed and networked environment, communication services play an important role in the gathering and dissemination of data among client and server processes.

Communication services must serve all of the platforms in the IVHS Network, and the communications software must be portable across the platforms.

Typical communication services for a networked environment include facilities for file transfer, network file access, remote procedure calls, protocol-independent network access, and data representation. Standards for many of these facilities are under development Unfortunately, it is expected that these standards will not be available until the end of the decade. Until then, existing standards will have to suffice, and the migration to the future standards will be achieved through vendor software upgrade paths.

Several common networking standards have been developed including the IBM System Network Architecture (SNA), the Digital Equipment Corporation DECnet, and the Department of Defense (DOD) Military Standard Protocols. The DOD Protocols have been in use for many years on ARPANET and the Internet. The facilities include TCP/IP (Transmission Control Protocol/Internet Protocol), FTP (Pile Transfer Protocol), SMTP (Simple Mail Transfer Protocol), and the TELNET Protocol as shown on Exhibit 6.14. These standards are supported across many platforms, in many languages, and by many off-the-shelf software packages. The DOD has committed to migrating from the DOD standard protocols to international standards. Considering the large base of equipment supported by the DOD, their protocols are expected to be supported well into the future.

The IVHS Network should be capable of supporting the DOD communication protocols, including TCP/IP, FTP, and TELNET. In addition, the network should be capable of supporting protocols including DECnet, a frequently-used protocol supported by systems from Digital Equipment Corporation. This will not only provide accessibility across many platforms, but it will also enable the use of many available communications packages.

Issue 3 - Open System Environment: Information Services

The IVHS Network will require use of Database Management Systems in a heterogeneous networked environment. Consistent interfaces between networked clients and servers will be required, allowing clients and servers to exist on different platforms. Data interchange services will be required to handle the exchange of data between different platforms.

Basic database services include the ability to access data and to perform searches based on potentially complex sets of conditions. Other operations include inserting, deleting, and updating records. The Database Management System must also provide facilities to ensure data integrity. Facilities must also exist to translate between data representation across platforms. As an example, the representation for a double precision floating point number on a Digital VAX computer is very different from that on a Sun workstation, and the database services must account for those differences when clients and servers communicate.

One of the standards in the Posix OSE information services area is the SQL standard (IS0 90751982). Many database products support the standard SQL interface. A variety of other products include the SQL interface to allow data to be imported from databases.

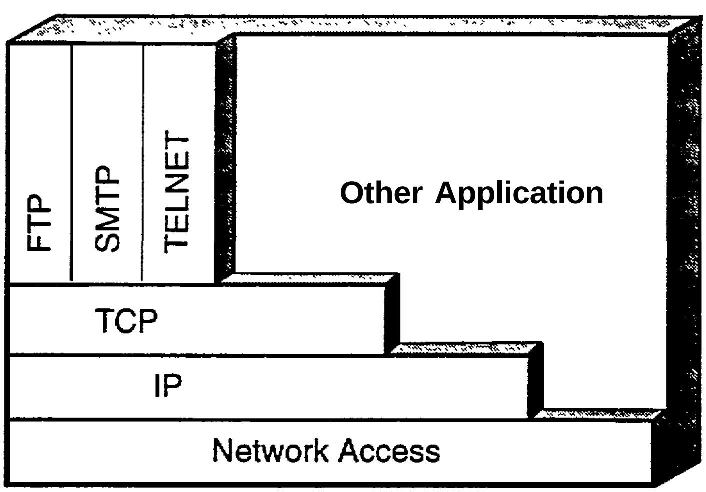
Data interchange standards are under development for data format protocols. In addition, because graphical data will play an important role in the IVHS Network, the Computer Graphics Metafile (ANSI X3.122-1986) may be important, because it provides a means for storing and exchanging graphical data. As standards are developed, they will be examined for inclusion into the system.

The OSF Distributed Computing Environment (DCE) provides facilities for data conversion between platforms. Several vendors are currently porting DCE software to their operating systems, and DCE should be available under UNIX, VMS, MVS, and MS-Windows in the near future. Use of DCE should be considered as a possible approach to the data interchange problem.

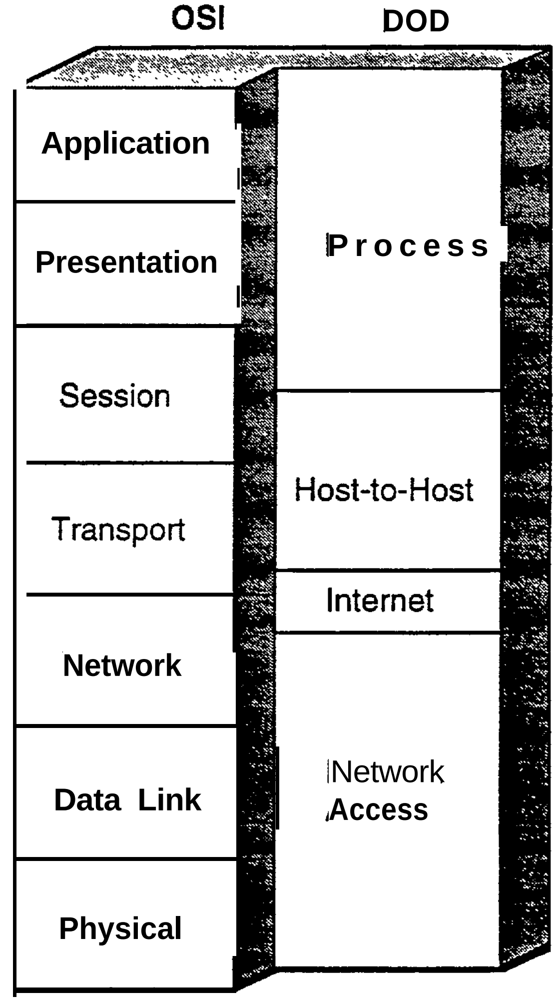
SQL is recommended for adoption as the standard interface for all of the databases in the IVHS Network This should enable the use of a many available software packages for database interaction. Even in a worst case scenario, where two DBMS systems would otherwise not interact, the SQL user interface may be used as bridge between the DBMSs All SQL commands and data may be expressed as ASCII character strings. Thus, a client/server pair could be constructed to build the strings, transmit them across the network, feed the strings to the SQL user interface, accept the returned data, and transmit the data back to the client in string form. The string format, while somewhat crude, eliminates the issues of bit and byte ordering in most cases.

The general data interchanges issue will require further study. The functionality and the availability of the OSF DCE software should be examined as a possible solution. Standards for

Exhibit 6.14
DOD Network Protocols



DOD Protocol Intetfaces



Comparison of OSI and DOD Communications Architecture

data files and file format conversions should be examined, especially in the area of GIS databases.

Issue 4 - Open System Environment: Human-Computer Interaction

With the variety of devices required for modern traffic management systems, combined with the necessity to integrate the operations of these elements, there are not only concurrent tasks required but also the need to monitor these simultaneously. With the staffing and space limitations of government agencies, this can be highly difficult if multiple, dedicated terminals are used, Likewise, in coordinating traffic data from a local system as well as that from another agency's system, it is necessary to be able to perform these tasks without interrupting other operations, including logging of information and carrying out routine system tasks. Hence, the requirements of the User Interface are for the ability to perform multiple tasks and provide multiple user "windows" for access by the System Operator to subsystem control facilities, as well as information (usually graphically presented) from other agency systems.

With the multiple system algorithms, applications, operating systems, and data sources which must be supported, a multi-tasking environment is essential. Such an environment is found in a Graphical User Interface (GUI) with full multi-tasking capabilities. A product such as Windows provides a GUI by basically acting as an overlay for the MS-DOS operating system, which does not allow for true multi-tasking for continuous processes. True multi-tasking GUI operating systems include the upcoming Windows NT, OS/2 (full multi-tasking plus graphical interface), and the Macintosh Operating System, as well as X-Windows, which is a GUI that has become the de facto standard with the multi-tasking UNIX Operating System and network environments.

The use of a multi-tasking GUI in conjunction with a GIS is underway at this time. Referred to as a Geo-Graphical User Interface by Insignares and Terry[5], the overall system performance can be improved through the use of spatially related elements. The use of object-oriented programming strategies provides these capabilities in the system. A key benefit of this interface is that multiple-linked applications and graphical, textual, and video images may be

[5] **Insignares and Terry**

displayed on an integrated ATMS workstation for an interactive, command, control, and monitoring environment.

The Graphical User Interface (GUI) should provide display and selection features which are uniform across platforms. The interface should use a standard protocol between application programs and display terminals. The interface should also conform to human factors standards.

The evolution of the GUI enables the integration of a number of different user services into one common control interface. This is the basis behind the integrated workstation concept as used for the Santa Monica Smart Corridor and currently proposed for the Cities of Anaheim and Santa Ana. Key attributes of a GUI applied to the Orange County IVHS Architecture are:

1. Presentation of data in text and graphical formats. This allows status information to be conveyed by color and graphical representation for ease of assimilation.

2. Accessing system information through a map of the system area. Such as using a mouse to point at a map where an icon shows the element location; "clicking" selects the element and retrieves current data regarding the element. Zooming in and out of the map allows for the view of larger areas but less detail or smaller areas with more detail.

3. Multitasking: Tasks run in "windows"; concurrent windows can be opened for carrying on parallel activities.

An example of a GUI is shown in Exhibit 6.15. This has been developed for the Smart Corridor Project. Points to note on the screens are the control of the CCTV through the GUI and presentation of the CCTV image in a window; the color coded, geographically correct map; and the overlapping windows using industry standard control techniques.

6.7.4 - Decision Support

For any incident management or traffic management strategy which affects multiple agencies, a series of decisions must be made which determine the goals of that strategy, and the various actions that must be taken for the corridor in question. The decision-making process can be facilitated through use of a decision support mechanism, which accesses the full range of

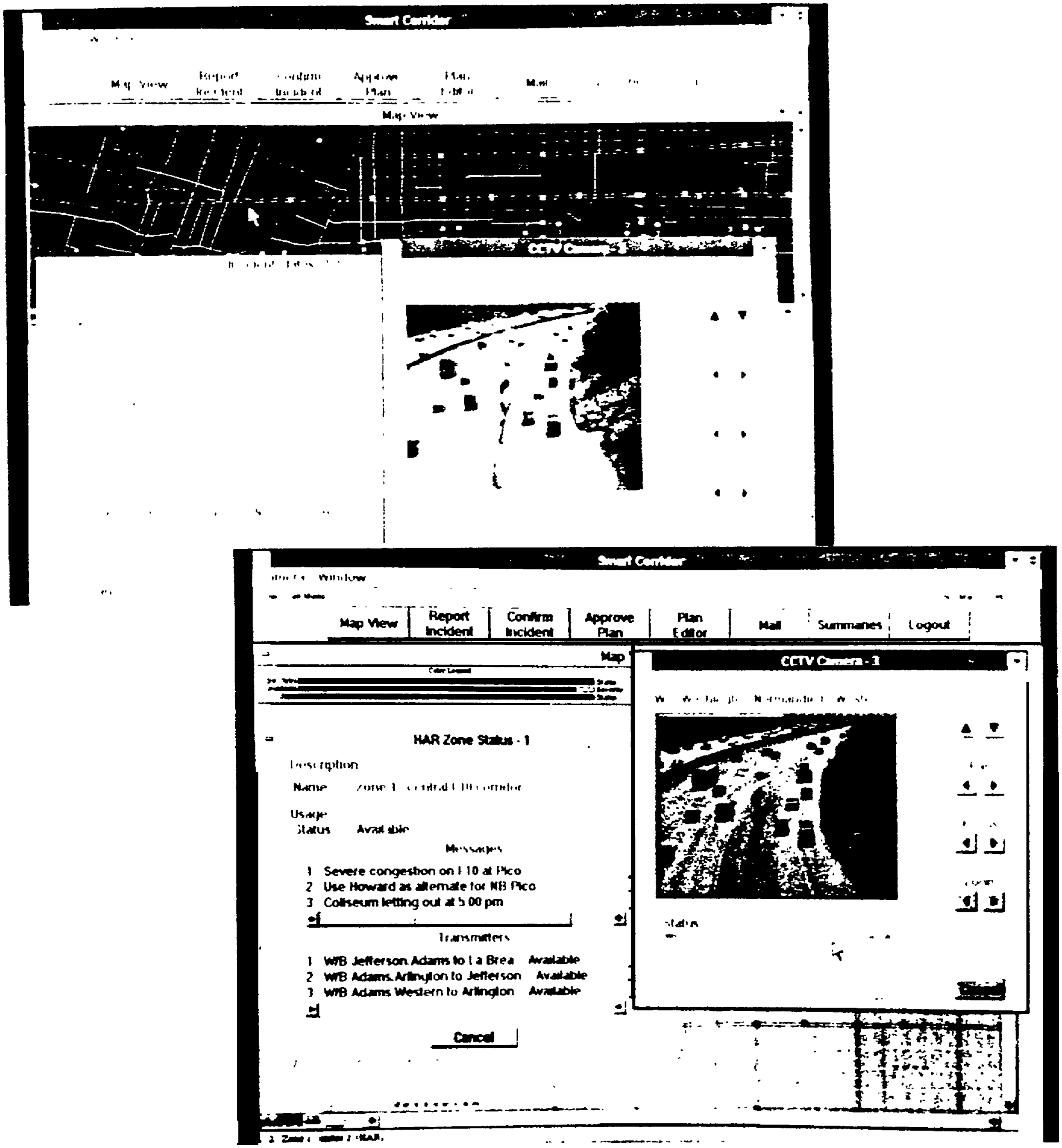


Exhibit 6.15
EXAMPLE OF OPERATOR INTERFACE
(SMART CORRIDOR WORKSTATION)

policy information (static information) and compares it with real-time traffic information. The quick correlation of incident reports and observations can lead to a more rapid incident confirmation. This in turn, allows a response strategy to be established more quickly. However, determining the best course of action, particularly as it involves a number of agencies, is highly dependent upon a good deal of professional judgement and experience.

Thus, the most useful decision support mechanism is a Knowledge-Based Expert System (KBES). An Expert System which correlates congestion or incident information can also be utilized to determine the appropriate strategies for various agencies to implement in coordination with their policies. Using a static database (the Rule Base), a number of strategies may be defined for the following:

- Traffic Management (response plans, including alternate routes, modifications to ramp meter rates, signal timings, CMS and HAR messages).
- Motorist Information (media information and other data to be transmitted to the public).
- Incident Management (appropriate contacts and procedures for more rapid removal of incidents).

The Rule Base is developed through an extensive process of operational planning, which for Orange County, would involve Caltrans, CHP, OCEMA, plus the 31 cities. Policies would be established for specific diversion routes, signal timing at key locations, CMS messages, and other operational' concerns. Such information would be coded as rules, and would contain operational threshold values for various traffic measures which will identify themselves when a response is required.

The dynamic database (the Knowledge Base), which extracts real-time data from the appropriate traffic management systems across the IVHS wide area network, provides the Expert System with the parameter values necessary to perform trade-off analyses and comparisons, and synthesize appropriate strategies and actions that are then presented to the various corridor agencies for approval. The recommendation could either be accepted in full by all the Agencies (i.e., System Operators) or modified based on additional real-time knowledge (i.e., weather, unscheduled special events) not ascertained by the Expert System. Based on this, the appropriate strategies are then sent automatically to the appropriate agency ATMS elements for implementation without the need for further Operator intervention. The Expert System also could provide the means for conflict resolution between different agency policies or strategies which do not support one another. This is particularly valuable for adjoining agencies which have different policies concerning using a specific roadway in a response plan, or between a regional agency (e.g., Caltrans) and local agencies.

strategies are then sent automatically to the appropriate agency ATMS elements for implementation without the need for further Operator intervention. The Expert System also could provide the means for conflict resolution between different agency policies or strategies which do not support one another. This is particularly valuable for adjoining agencies which have different policies concerning using a specific roadway in a response plan, or between a regional agency (e.g., Caltrans) and local agencies.

7

System Configuration for Information Sharing and Dissemination

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7. SYSTEM CONFIGURATION FOR INFORMATION SHARING AND DISSEMINATION

7.1 INTRODUCTION

The purpose of this Chapter is to assess the communication and interface needs for the ultimate IVHS network both as a function of system-to-roadway communications and of interagency communications requirements. The recommendations from this Chapter will be the following:

- A recommended functional layout for County-wide IVHS elements based on the recommended architecture in Chapter 5.
- Identification of communication links and data requirements for central-to-local communications in terms of trunk and distribution links, as well as between agencies (central-to-central links, often called "interties")
- Identification of recommended communication protocols between system elements.

The communications network is perhaps the costliest component of the IVHS architecture. It is also, next to the computer and processing components of the system, the most technically volatile. Technologies and applications are being developed continuously which result in expanded capabilities at lower costs.

7.2 FUNCTIONAL LAYOUT OF IVHS NETWORK

It is obvious that the underlying theme of IVHS implementation relative to existing traffic management systems in Orange County must be one of developing standard communications and data links between different system types.

To develop this complex network, it is first important to understand some basic-level elements of traffic operations, particularly with regard to local-level operations. These elements, as they are developed, increasingly satisfy overall transportation objectives in the County.

Traffic control equipment within the IVHS network will range from isolated intersection controller to systems involving the integration of diverse system components and those coordinating arterial and freeway operations (such as the proposed Smart Corridors identified in Part I). The system elements must be designed in such a way that the correct systems are implemented to support both local and regional needs.

The following analyzes how a structured approach can be taken to define the development of a traffic management systems infrastructure for Orange County. This shows how various transportation objectives are supported and therefore allows the local system elements to be defined in terms of the countywide infrastructure.

Exhibit 7.1 relates the various stages in the implementation of traffic signal control to the system objectives. Several levels of deployment are addressed, spanning local inter-jurisdictional and regional deployment.

At the lowest level, traffic signal control of intersections can be warranted due to safety improvements and delay (congestion) reduction. Synchronization coordination of intersections allows for the provision of such benefits over a larger area such as an arterial.

Operations and maintenance are supported at the next level in which two-way communications are established with the field equipment. Note that this is the level at which system detectors provide for real-time data collection. This is the lowest level which is to be accommodated within the IVHS network.

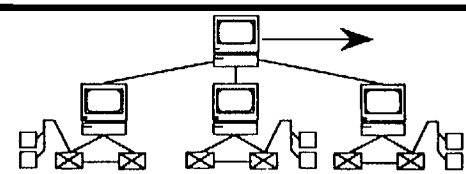
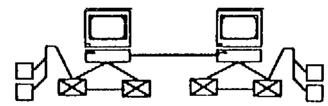
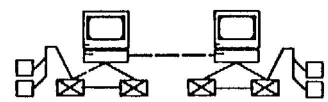
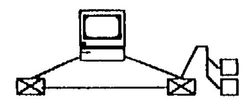
At the next stage, inter-jurisdictional coordination can be readily accomplished using the WWV technique at the system level and utilizing a common cycle base reference algorithm in adjacent systems. Such coordination is currently being implemented in the County on such roads as Katella Avenue, through a number of jurisdictions.

Transfer and interchange of system data occurs at the next level. This allows management procedures and policies to be implemented on a regional basis. Area-wide views of congestion and other traffic conditions in real time. Examples of this are the interties between Caltrans District 7’s freeway traffic management system (SATMS), Caltrans District 12, and the Anaheim, the Los Angeles, and Pasadena systems.

Finally, region-wide data sharing and coordination is achieved at the last level. This is typified by such systems as the Santa Monica Freeway Smart Corridor system in Los Angeles which is currently being implemented. Operator decision support systems extract data from the

Exhibit 7.1
IMPLEMENTATION OF ARTERIAL ATMS ELEMENTS

Objectives

Level of Implementation	Increase Safety	Reduce Local Congestion	Reduce Regional Congestion	Improve Reliability	Provide Pre-Trip/ En-Route Info	Support TDM Policies	Sketch
Integrated System Region-Wide Data Sharing & Coordination							
Inter-System 2-Way Communications (Interties)							
Inter-System Synchronization (WWV)							
2-Way Central-Local Communications							
Synchronized Intersections							
Local Intersection Control							

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local systems and provide system wide analysis tools. Coordinated interagency responses are enabled through ‘down-links’ to the local systems. The actual system architecture resulting from the concepts presented in this IVHS Study are to provide the infrastructure for such a region-wide system.

7.2.1 - Maintenance of Local Automony

As discussed in Chapters 4 and 5, a key issue in development of the IVHS architecture is providing the capability for agencies to work with one another in coordination of traffic operations. At the same time, however, the issue of autonomy of control is important, as agencies in general do not want to give up jurisdiction of equipment or facilities that are currently under their control or perview.

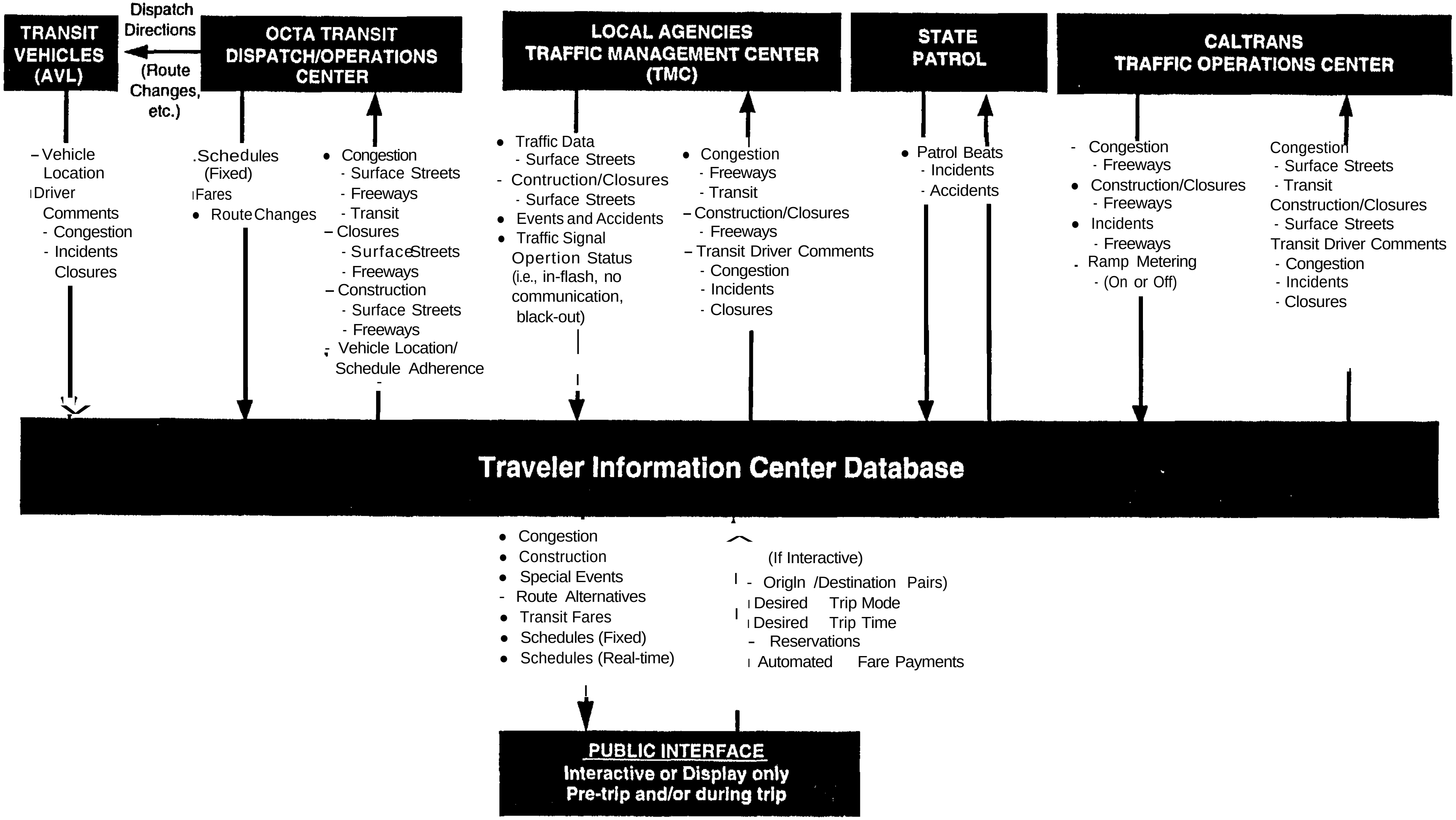
7.2.2 - Overall Data-Sharing Scheme

As shown in Exhibit 7.2 in terms of specific data paths, the basic architecture framework will be one of a central Traveler Information Center (TIC), which coordinates information received from local agencies and then disseminates the information to a wide range of users. In addition, the use of Expert Systems for Caltrans and local agencies for each of the five Smart Corridors would correlate the information for the purpose of decision support for real-time traffic management and incident response strategies.

7.2.3 - Compatibility of Data

An underlying source of complexity in the overall system is the shear number of interties between local agencies and the Traveler Information Center (TIC), as well as the variety of platforms and sources from which information is gathered. In essence, this represents one of the most difficult IVHS elements to implement. To do this, a method is required to assure that the compatibility and content of the data will be what is required for global traveler information and decision support, two of the main facets of the IVHS network.

Exhibit 7.2
DATA PATHS



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The maintenance of local autonomy, as discussed above, naturally extends to the choice of system operations platforms. For example, traffic signal control systems in the County range from large, centrally-based UTCS systems such as Anaheim, to centrally-based proprietary central systems (Multisonics VMS), to various types of PC-based systems with distributed intelligence (QuicNet). The sharing of data between these different platforms is at first glance difficult, since many of the systems do not have external data links or external user control capabilities. In order for this to occur, it is necessary to define traffic data and control requirements, sampling rate and any other information that is needed.

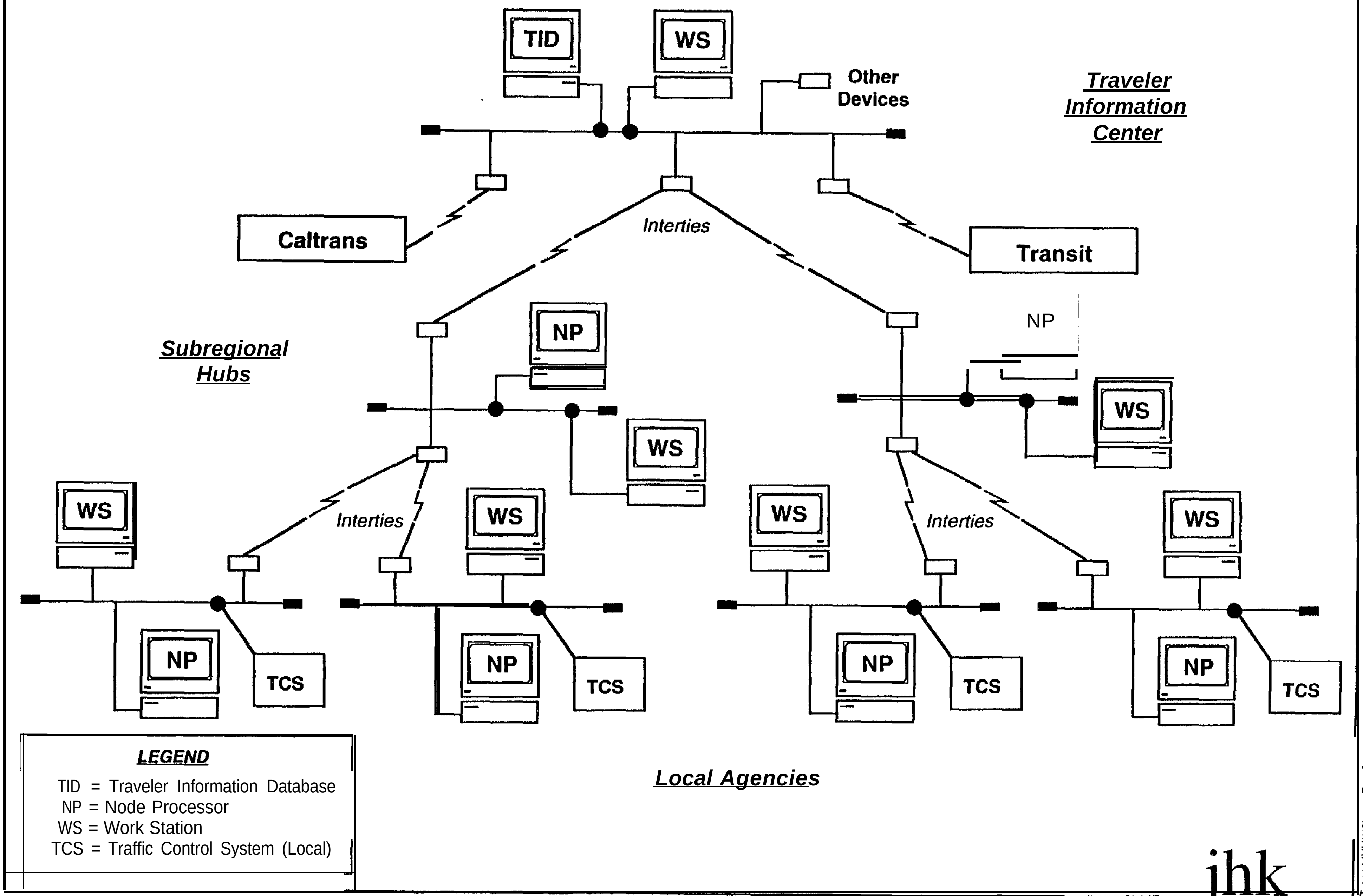
To summarize, the basic communications and control system infrastructure for surface street operations in an M-IS Network requires the following at a minimum:

- Two-way central-to-field communications capability.
- Provision of intersection controller status, timing, major street green.
- Traffic information from strategically placed system detectors located a minimum of 300 feet from the nearest stop line, and further back as needed to sample "free flow" surface street traffic.
- Ability to export traffic and signal data from the traffic control system.
- Ability to receive external control commands for selection of signal timing plans or requests for specific information from the local control system.

For the freeway network, the Caltrans Traffic Operations System (TOS) for District 12 will involve the development of a central computer capable of two-way communications with field devices, including ramp meters and system detectors located at 1/2 mile or better spacings. In addition, subsystems consisting of changeable message signs (CMS), closed-circuit television (CCTV), and Highway Advisory radio (HAR) are being developed and expanded in District 12.

The freeway system will need to be capable of exporting traffic information and status information (e.g., metering on, CMS messages) at a minimum in order to support the basic traffic information needs of IVHS. In addition, the transmission of video from the TOS could allow visual images on the freeway to be reviewed by local agencies, for assistance in the development of specific traffic response strategies. Likewise, surface street CCTV information, where

Exhibit 7.3
Three-Tier Approach
IVHS Architecture



Transit IVHS/Three - Tier Approach

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available, could be reviewed by Caltrans to assist in development of appropriate response strategies along the freeway.

7.2.4 - The Proposed IVHS Architecture

By defining the external data links at a local level, a “node processor” can be developed at the local system which takes this information and converts it to a standardized protocol. A network of local node processors would allow for seamless transmission of data between agencies and would provide a standard Countywide interface to the regional levels of operation and coordination, such that information from all local agencies can be evaluated and utilized in the same manner.

An example of this opportunity for external link development has occurred for the Cities of Santa Ana and Irvine. An upgrade to the existing Multisonics VMS signal system is including a means of exporting information to a Local Area Network (LAN) through a node processor. In turn, the signal system will be capable of receiving external control commands with regard to timing plan selection and data requests. These commands, from extemal workstations or, in the future, a Smart Corridor Expert System, would be passed through the node processor, where it is then converted to the agreed protocol as developed by the signal system manufacturer.

To provide greater efficiency in development of the network and reduce costs associated with data sharing, it is proposed that a three-tier system of data sharing occur at the local level. This is shown in Exhibit 7.3. The first tier would be the local agencies, where a node processor would have the duties of sending traffic and signal status information from a City’s signal system and in turn, being able to receive information from other agencies Concerning freeway conditions, traffic and signal status on roadways leading into the City, and other information as desired.

The second tier involves the use of subregional hubs. These subregional hubs allow for exchange of data directly between groups of agencies through a standardized protocol such as TCP/IP. This would be accomplished through a single intermediate level node processor per defined subregion, which would gather information from the local node processors for exchange with each other, as well as for transmissions to and from the TIC’s database.

The third tier would gather all the information from intermediate node processors as well as from the OCTA Transit Operations Center and from the Caltrans District 12 TOC. This third tier would then have the responsibility of correlating the information, and either desseminating it to the public and to the operations agencies through various means, or utilizing it to provide coordinated real-time Smart Corridor traffic management strategies through the use of Expert Systems. These plans would be issued for acceptance by local agencies during specific conditions.

A functional layout of proposed county-wide IVHS components is presented in Exhibit 7.4, and illustrates the links between local or multi-agency ATMS systems, the Caltrans TOS, the TID and various Smart Corridor systems, as well as other system users. As is apparent, this network would be intended to encompass and accommodate virtually any element which is added to the countywide MIS program. Workstations will provide for the graphical display of information of all points in the network.

At the Traveler Information Center (TIC) level, a Data Manager would gather traffic data from the different agencies and provide any necessary processing in order to develop congestion measures. This information is then sent to a Traveler Information Database (TID), the function of which is to serve as a clearinghouse for all real-time congestion, incident and other operations information, as well as appropriate transit status information. The TID will be the basis for centralized dissemination of transportation information.

The communications and data-loading requirements for the system are discussed in greater detail below, along with the suggested standards for system-to-system and field-to-system communications.

7.3 SYSTEM CONCEPTS

As has been discussed elsewhere throughout this Study, the IVHS network can build upon a number of backbone elements which have been developed individually, including individual City Traffic Management Systems (such as the Anaheim existing system, plus the Irvine and Santa Ana systems now under development), as well as the existing and planned elements of the Caltrans District 12 Traffic Operations System.

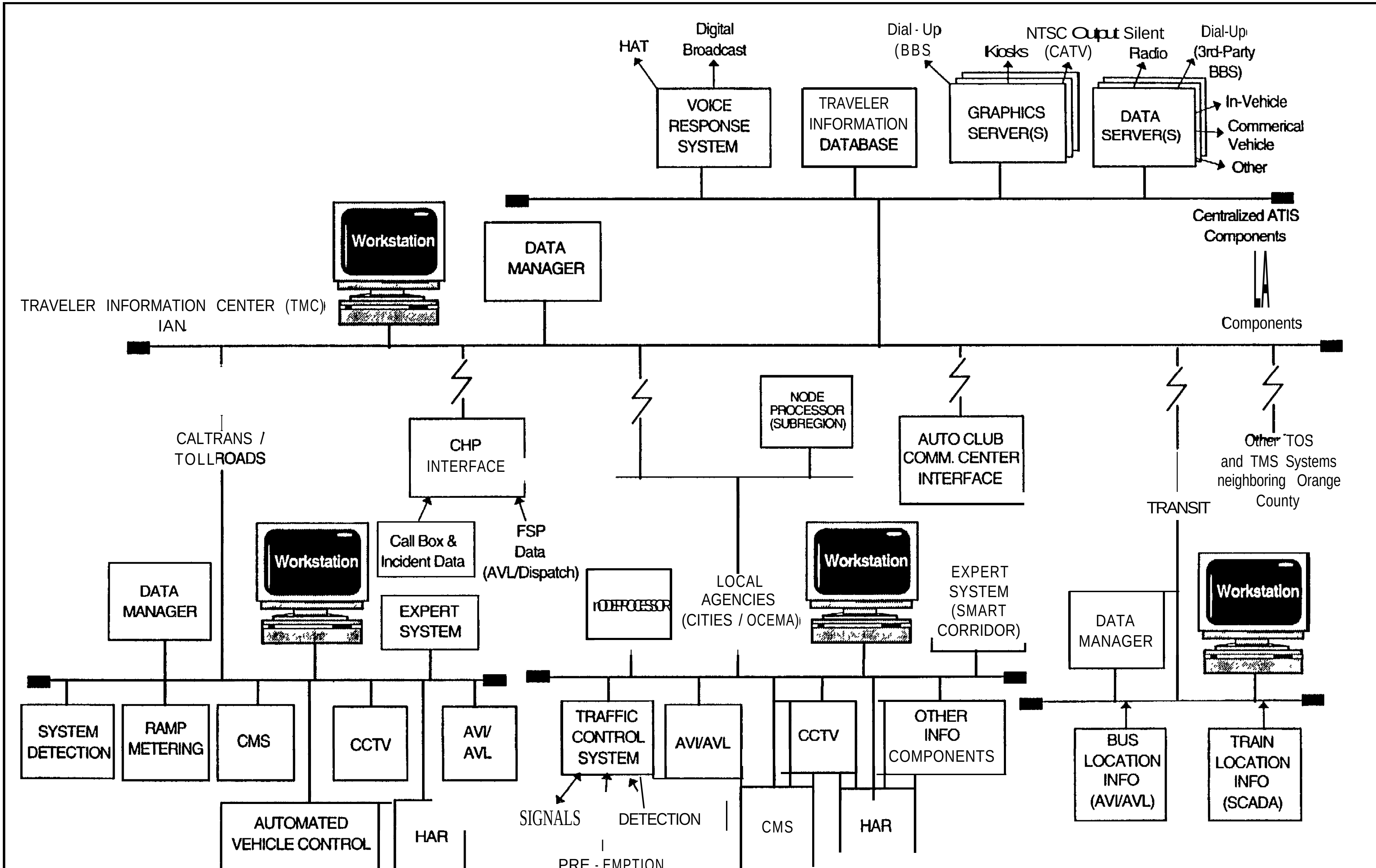

Exhibit 7.4
FUNCTIONAL LAYOUT OF ORANGE COUNTY IVHS ARCHITECTURE

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Associated with the expansion of existing elements is the need to create a linked network of local and regional IVHS elements. The implementation of regional, multi-agency, operational and information strategies requires the ability for systems to communicate with one another for the purpose of exchanging information. The nature of the preferred IVHS architecture, as described in Task 2, is a combination of distributed intelligence complemented by centralized coordination capabilities.

7.3.1 - Current Technical Constraints

The need for distributed intelligence with central coordination raises the issue of existing compatibility between different system elements, traffic signal control in particular. As has been discussed elsewhere throughout this study, although over 80% of traffic signals in Orange County utilize some form of central coordination, most of the central systems are not capable of "talking" to one another. The issue is also true with controllers. Traffic signals along Caltrans facilities (freeway interchanges and state routes) are of one type (Type 170 microprocessor with serial full-duplex communications interface), while local signal controllers adjoining the Caltrans facilities may be different from a Type 170 and have a completely incompatible communications protocol.

An initial method of signal coordination between agencies, as has been incorporated into the OCUTT projects, has been to utilize WWV time clocks to synchronize operations. The advantage of this is the relatively low hardware cost, plus the opportunity of interagency strategies in developing time-of-day/day-of-week (TOD/DOW) signal timing plans, particularly in terms of cycle length and offset development.

In terms of field-controlled, centrally-supervised IVHS elements (not just traffic signals), this coordination must be taken one step further, as discussed below. However, it is important, from a cost standpoint, to recognize that central-to-central communications are a greater concern than are central-field communications, provided that proper field data and control capabilities are possible with existing protocols.

7.3.2 - Open Systems

An "open system" can be simplistically described as a system which is capable of receiving information' from anywhere and sending information where it desires using interfaces employing industry standard data structures and protocols. Section 6.7.3 provided an in-depth discussion of open system concepts. In reality, the open system is constrained by the characteristics of the network links, including data capacity and transmission rate of the communication network and compatibility between vendor products.

Exhibit 7.5 illustrates the typical communication requirements between central and field devices, and then between different users (e.g., agencies). For example, feedback data (e.g., detector status and traffic measurements, display status) should be accessible to users outside the immediate agency for use in assessing roadway conditions as well as developing a real-time control strategy to address a specific traffic condition, such as those related to special events or diversions from the freeway.

Likewise, the provision of upload/download capability in both the field controllers and in the communications link is essential for three reasons. First, from an operational point-of-view, it allows adjustments in control settings such as signal timings without the need to perform this task individually in the field for each controller, thus saving substantial labor costs.

Secondly, from the standpoint of maintenance and "default" operations, upload/download of operational data allows for field back-up operations, and in the case of one system failure, the ability for access from another user interface as needed.

In the case of a traffic signal control system, when a central system goes offline for any reason (or if the communications link is severed), this allows coordination to be maintained in the field, through use of one controller as a "master" time base for other controllers, or through time synchronization via WWV.

Finally, the ability of field controllers to store information reduces the need for second-by-second central control. This reduces communications requirements, and allows the central system to obtain more field information, as well as download any immediate operational changes (e.g., signal timings, CMS messages) to the controller so they can be implemented locally. Second-by-second status monitoring is still desirable, however.

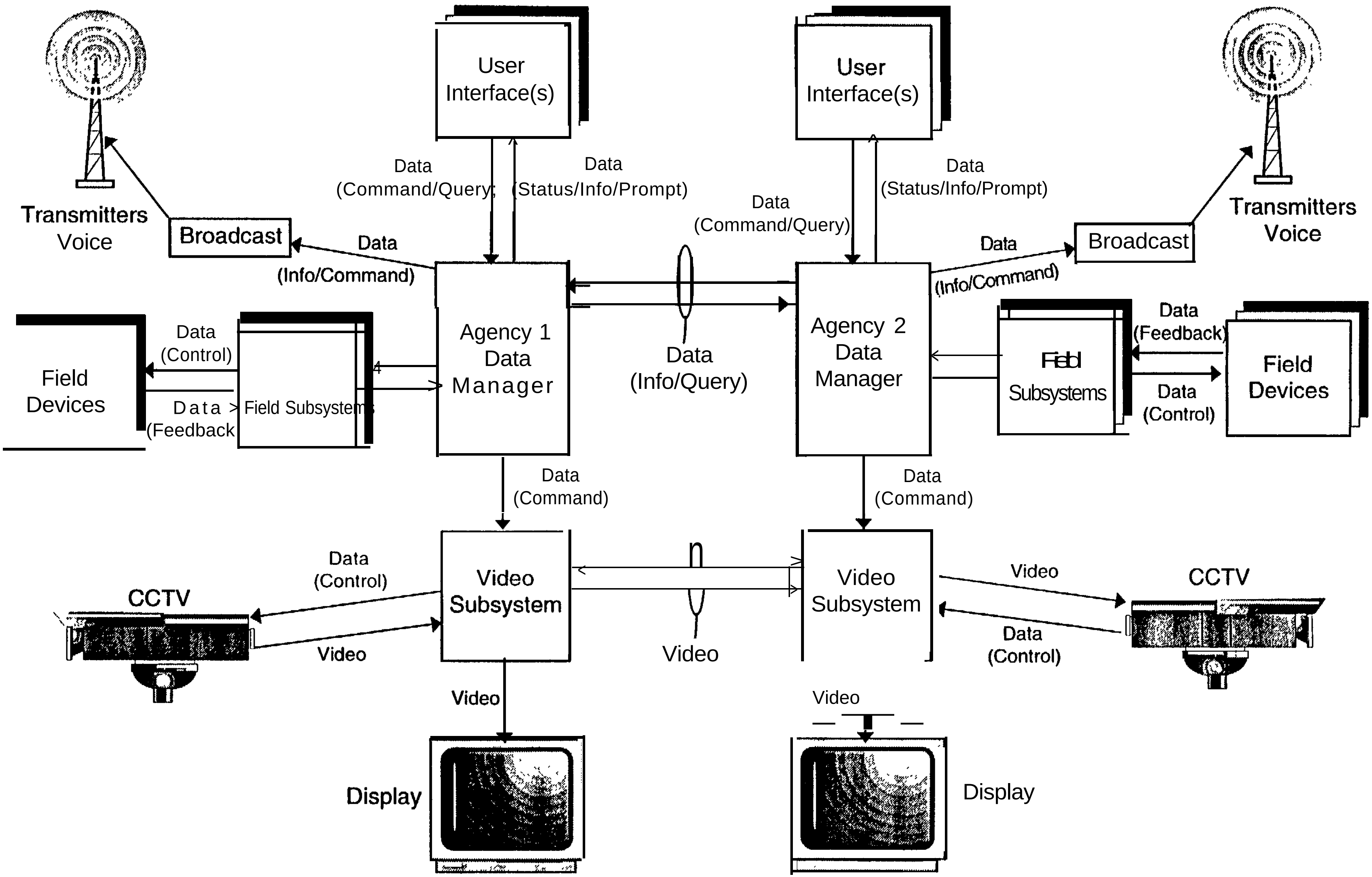

Exhibit 7.5
TYPICAL COMMUNICATIONS AND DATA EXCHANGE BETWEEN SYSTEMS

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These benefits are also evident with Changeable Message Signs (CMS). Though CMS use is typically based on real-time need, not a default TOD/DOW condition, there is still great benefit to storing commonly used messages or message units at the field controller. The user would have access (through a central server device) to the specific CMS controller and could thus specify a message number rather than sending a full message command Again, this reduces communications loading, and a full-duplex communications interface allows for uploading and downloading of messages either for immediate display or for storage in the field controller as a “pre-stored” message.

As long as a standard data access capability and communications protocol is defined throughout the county-wide IVHS network for communications between agencies, it should not be necessary to specify a single central system or controller type or central-field protocol throughout the County, so long as the components have the capability of providing the necessary data and operational functionality to support the requirements.

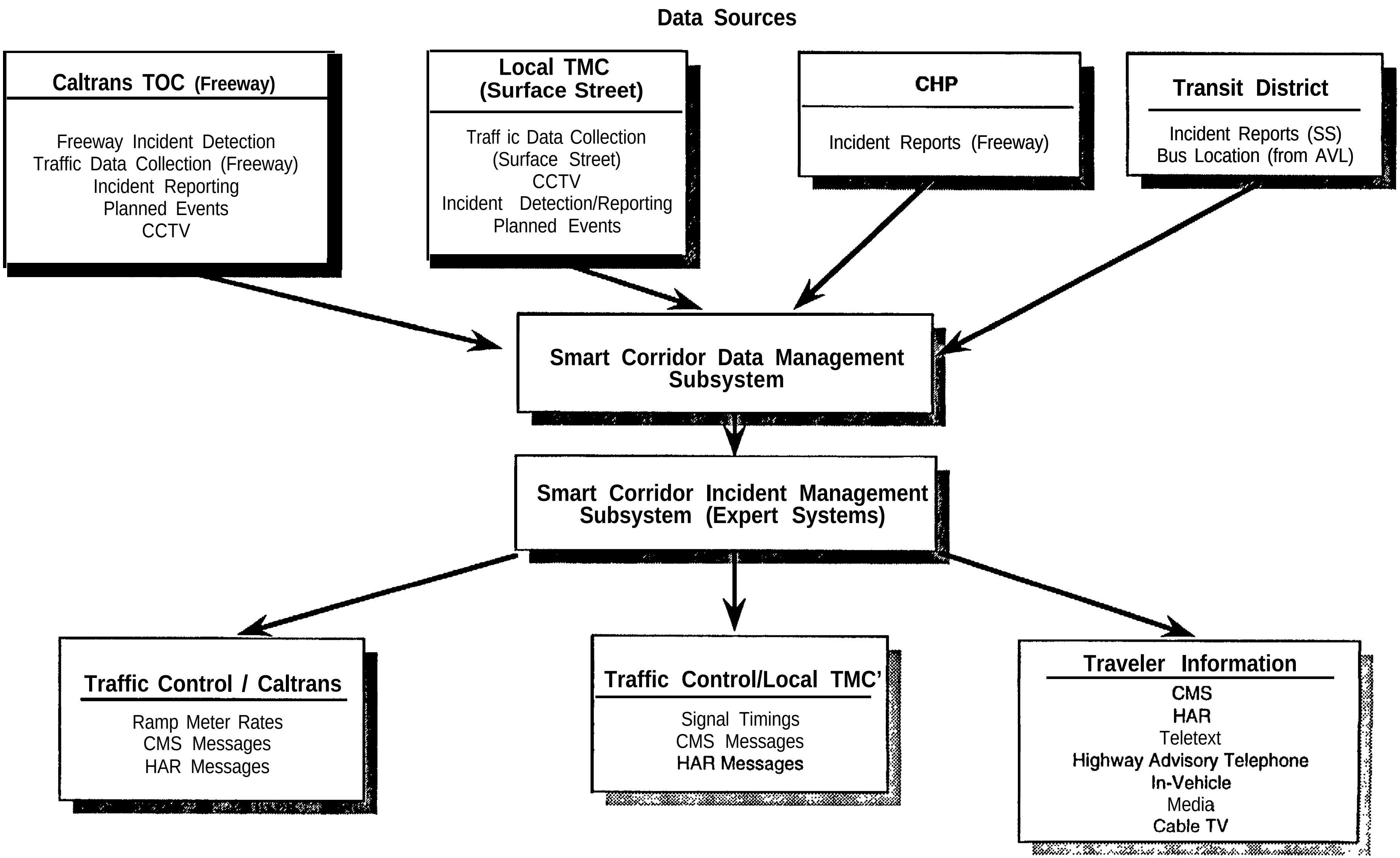
7.3.3 - Smart Corridors

A “Smart Corridor” strategy, as defined in the Smart Corridor Statewide Study prepared for Caltrans, optimizes corridor operations through balancing of traffic flows between freeways and surface street.

A coordinated interagency strategy as is required for the “Smart Corridor” concept requires both the use of coordinated response plans and agency confirmation that specific elements under their jurisdiction can be utilized. This is done through the use of communications links between systems for both exchange of information and exchange of commands.

The nature of the “Smart Corridor” technical concept (see Exhibit 7.6) is that a decision-support system, usually a Knowledge-Based Expert System (KBES) is fed all the information for a specific corridor from all the constituent data collection resources from various systems. Based

Exhibit 7.6
Smart Corridor Base Functions



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incident for Operator confirmation, a recommended combination of freeway and surface street CMS's warning of 2 specific incident and traffic condition, and a set of signal timings along a recommended diversion route. Exhibit 6.15 in Chapter 6 showed an example of the Smart Corridor operation interface.

Once the agency staff approve the response plan, implementation of the response plan requires direct communication to the various control systems. In terms of a control plan affecting multiple agencies, particularly a signal timing plan, coordination between adjacent systems is absolutely necessary. In cases where a small number of signals are impacted in the first system, but are adjacent to an adjoining second system, it should be possible for these signals to come under the temporary control of the second system, either through direct communications links or through commands passed along to the first system.

Thus, the nature of open systems architecture is that full flexibility of control and information exists, thus ideally "obliterating" jurisdictional boundaries.

It is expected that Expert Systems will be provided for each Smart Corridor. (Six Corridors have been identified). The system platforms would be located at Caltrans and at each of the TMC's which would have jurisdiction over arterial roadways within the Smart Corridors.

The Smart Corridors would function in an integrated fashion within the architecture. In general, specific data will be accessed directly from local agencies and Caltrans through the communications network. Traffic control actions would be transmitted directly to the local agencies and Caltrans. Traveler information actions (i.e., recommended media messages, HAT messages, in-vehicle navigation directives) would be sent to the Traveler Information Database (TID) for dissemination. In addition, the Expert Systems would access TID information provided from CHP or other agencies.

7.4 DEFINITION OF INFORMATION REQUIREMENTS

The overall IVHS communications system is to provide networked communications service for traffic operations, enforcement, motorist aid, emergency services, mass transportation, motorist information, and maintenance activities.

The communications network will be an integral part of IVHS in that it will affect (and be affected by) system architecture, configuration, and operational strategies. In addition, the design of the communications network must be robust to provide reliable service for twenty years or more. Currently, the extent of technological change and market restructuring present real problems of potential system obsolescence in a relatively short time frame. With obsolete systems, comes either high maintenance costs or premature replacement of equipment. Accordingly, the communications system for the ATMS must provide a flexible, open architecture and conform to major trends in the market.

The information and communications requirements for the proposed County-wide IVHS network are summarized below.

- Concealed Network Operation - The operation of any large multi-agency system is necessarily complex, but it must appear simple to the system users who will be engaged in other operations.
- Support of a Wide Range of Uses - The IVHS network will have a number of separate voice, data, and video systems each with separate requirements which is unusual in the general communications industry.
- Support of a Wide Range of Data Systems - There will be several different types of data communications systems both at the outset and especially in the future, all of which must provide compatibility with the IVHS network.
- Support of a Wide Range of Topologies - The network topology is determined by the need for field equipment at particular locations as well as available agency facilities and existing systems.
- Use of Communications Standards - Standards are critical to diverse equipment use of the network and to future enhancements and migration.
- Robustness - Even as important as the basic availability requirement, the IVHS network must be suitable for operation in unusual and disaster scenario circumstances.
- High Availability - A continually operating system is needed with a very low probability of system failure and equipment failures causing only partial outages. A level of redundancy is required which allows for basic functions (traffic control, essential traveler information) to be carried out at all times.
- Maintainability - The effort of maintaining the system must be in line with available agency staffing and resources.

- Network Modularity. The communication system must allow a phased implementation, asymmetrical growth, and cost efficient location of facilities, including regional TMCs, the Caltrans District 12 TOC and the Central TIC facility.

- Capacity Growth Capability - The Communication system must allow expansion of the number of devices on an already installed portion of network (e.g., freeway TOS, existing local TMS) and a progressive network expansion under operation

- Manageability - Some functions cannot be automated and those for which can be automated it is sometimes necessary to manually override that automation. This is particularly true in large or complex networks. The communications network must be manageable from multiple locations, and if necessary, through use of remote facilities.

- Future Enhancement Capability - The network will need to handle equipment and messages for future technologies, many of which are as yet undefined or undeveloped. There must be a high probability that new designs will include interfaces of this network. Specifically, the incorporation of AVCS must be considered even in development of near-term system elements.

7.4.1 - Communications Functions

The following communication links are required in the proposed IVHS architecture. They are described below and can be correlated in both Exhibit 7.2 (Data Paths) as well as in Exhibit 7.4 (Functional Layout).

7.4.1.1 - Traveler Information Center

The Traveler Information Center (TIC) will serve as the central clearing house of information regarding the County's transportation network. Thus the TIC must be serviced by a communications network capable of both receiving and transmitting data from and to individual agencies and sub-regional centers (e.g., TOC, TMC's, transit operations), on a County wide basis.

These communications links may consist of leased lines existing or new twisted-pair or fiber optic links, microwave radio where line-of-sight paths exist, or satellite links. It will be desirable for several agencies to have the capability to transmit and receive CCTV images, thus, those links must have the capability to handle video with a minimum data rate of 112 Kbps (this allows for compressed video transmission).

Additionally, the TIC will disseminate information to the various traveler information stations. These may include Community Access Television (CATV) broadcasts, kiosks, BBS, etc. and can utilize communications links such as leased lines from Pacific Bell to CATV and kiosks, and possibly wire-less links such as spread spectrum to LED signs at bus shelters.

7.4.1.2 - Traffic Operations/Management

A reliable, cost-effective communications architecture must be designed to accommodate the connection of thousands of field devices to the Traffic Operation Center (TOC) or to local Traffic Management Centers (TMC's). These devices are distributed over hundreds of miles and are often located far from existing communications networks (e.g., Pacific Bell).

The general design of the traffic operations architecture consists of trunk communications which connect the TOC and TMCs to communications hubs located in the field, and local area communications which connect each field device to a communications hub. The trunk communications may consist of a combination of leased lines from Pacific Bell, agency owned twisted pair and fiber-optic cable, and possibly satellite links. These lines range in capacity from 56 kbps to 44 Mbps, depending on the requirements of the devices which are connected to the local hub. Local area communications may be accomplished using twisted pair cable, fiber-optic cable, and networked spread-spectrum radios. The data rate on these links is low, and typically consists of 1200 to 9600 baud data circuits in a multi-drop configuration to as many as twenty controllers.

7.4.1.3 - Transit Operations

Transit operations requires the transmission of data both between stationary locations (e.g., vehicle service center and central) and between mobile and stationary locations (e.g., transit vehicle and central). These links may consist of leased lines, agency owned cable, and a variety of wireless communications such as two way radio and satellite (supplying AVL information).

7.4.1.4 - Communication with Enforcement Agencies

The TIC will provide information to cognizant enforcement agencies using both computer links. These links can be either dedicated or dial-up, depending on the nature of the equipment at each end of the link. The computer links will be supplemented by voice links with the TOC/TMCs. The computer link will provide information to Computer Aided Dispatching (CAD) equipment, while the voice link will be used to converse directly with enforcement personnel.

7.4.1.5 - Communication with Emergency Services

Information exchange between the TOC/TMCs and Police, Fire, Hazardous Material, and Service Patrols will use both direct voice links and data links via the TIC. Either dial-up or dedicated links could be established, depending on the requirements of the individual agencies.

7.4.1.6 - Communication to Motorist Information Devices

Motorist information equipment includes both changeable message signs and highway advisory radio. This equipment is considered as field devices and communications from/to the equipment will use the traffic operations links as discussed above.

7.4.1 7 - Interagency Communication

Dependant upon the local and subregional traffic control configurations decided upon by the GMAs and local agencies, based on the structure given in Section 7.2, computer-to-computer links would be established between local agencies and sub-regional hubs, with similar links between the hubs and the TIC. Assessment of required data transfer requirements must be done as part of a detailed system design effort. As a minimum, however, these links must be standardized in terms of data structure and protocol. A desirable standard to use is Ethernet TCP/IP used regularly for linking workstations

7.4.2 - Communications Technologies

The heart of a communications system is the transmission medium. Each communications medium has inherent characteristics -- such as frequency response and bandwidth, susceptibility to interference and noise, allowable data rate, repeater requirements, physical constraints, etc. -- which determine its suitability for use in this system. Applicable communications technologies were discussed in Section 6.2. These included fiber-optics, leased lines, twisted pair cable, spread-spectrum radio, microwave radio, satellite, and cellular radio.

Designs employing the alternative technologies will need to be developed and evaluated based on their ability to meet the system's requirements and at what cost. Typically a cost utility analysis technique is employed which enables a balance between equipment capability and cost to be established for each of the candidate systems. Each feature or function is "scored" and "weighted"; the sum of the products of the scores and weights gives the overall utility of the candidate. Dividing the cost by the utility provides a numeric value for comparison purposes.

7.4.3 - Field Device Considerations

The Traffic Operations communication system must accommodate a variety of field devices. The data rates and frequency of communications varies greatly among the devices. The design of the communications systems must take into account the requirements of each connected device, as well as the number and types of devices in a local communications hub. Exhibit 7.7 and Exhibit 7.8 contain general characteristics of typical equipment, including data exchange rates, sizes, and frequencies.

7.4.3.1 - Detection Station, Traffic Signal. and Ramp Controllers

Traffic Signals, detector stations, and ramp meters use the same controller hardware, typically a Type 170 controller or NEMA equivalent. They will be located at freeway interchanges and at intervals along the freeway as well as at each signalized intersection along the major arterials. These devices will communicate with processors in the communications hub on a regular, polled, full time basis, and require two-way communications.

EXHIBIT 7.7
FREEWAY EQUIPMENT

Equipment	Information Flow Direction	Interface Data Rate	Length of Exchange	Frequency
Detector Stations	To TOC	1200 %00 bps	100-200 bytes	15-30 seconds
Ramp Meters	From TOC	1200- %00 bps	< 20 bytes	On Demand
Changeable Message Signs	From TOC	1200 9600 bps	10-100 bytes	On Demand
Highway Advisory Radio	From TOC	56 kbps	< 30 seconds of audio	On Demand
Video Surveillance				
– Full Motion	To TOC	Analog 6MHz Bandwidth	Duration of Incident	On Demand
– Compressed	To TOC	112 kbps		

Camera control information (pan, zoom, etc.) flows from TOC to video equipment.

EXHIBIT 7.8
MAJOR ARTERIAL EQUIPMENT

Equipment	Information Flow Direction	Interface Data Rate	Length of Exchange	Frequency
Detector Stations	To TMC	1200- 9600 bps	3 bytes control +3 bytes/detector	every 30 seconds
Traffic Signal Control	From TMC	1200- %00 bps	Bi-directional 8 bytes to/from TMC	Once/second
Full Matrix Changeable Message Signs	From TMC	1200-9600 bps	250 bytes MAX	On Demand
Video Surveillance			Duration of Incident	On Demand
– Full Motion	To TMC	Analog 3MHz Bandwidth		
– Compressed	To TMC *	112 kbps		
Highway Advisory Radio	From TMC	56 kbps	< 30 seconds	On Demand
Limited Message CMS (Trailblazer)	From TMC	1200- 9600 bps	250 bytes MAX	On Demand

Camera control information (pan, zoom, etc.) flows from TMC to video equipment.

These controllers will require a 1200-9600 bps data circuit which can be in a multidropped configuration on a single channel (full-duplex).

7.4.3.2 - Changeable-Message Signs

Both full matrix changeable message signs and limited message changeable message signs (trailblazers) use the same type of data channel as the detectors, signals, and meter controllers, communicating at 1200-9600 bps. The communications requirement for CMS is a low rate, on demand type link. Dial-up leased line or cellular links are ideal, since the actual use of these communications paths will probably be less than 10 percent.

7.4.3.3 - Highway Advisory Radio

The highway advisory radio (HAR) communications requirement are for a clear voice channel or medium high rate data channel. Typical HARs support the broadcast of both prerecorded messages and messages which are sent to the HAR by the TOC/TMC. Either a cellular telephone or wire communications is used to transfer messages to the HAR. Leased 56 kbps digital circuits are now used by commercial broadcast radio with special equipment for 7.5 kHz voice ("broadcast quality voice") and could be used for the HAR. The HAR communications requirement is for 100 percent availability, but with such little use, as it is not necessary for a constant connection a constant connection is normally required, however, to check operation and verify what message is broadcast.

7.4.3.4 - Video Equipment

The major purpose of video surveillance is incident verification, which requires only short duration visual information. However, the video network will have to be available 100 percent of the time for incident verification and other surveillance functions, though the time that most cameras will be used will be relatively small.

Two different types of video communications circuits are envisioned for the TOC/TMCs. In those areas where a fiber-optic backbone is installed, the video transmissions will be full motion analog. The video signal will be multiplexed onto the backbone fiber network. In those areas where other types of trunk communications must be used (e.g., leased line networks), compressed digital (i.e., CODEC) video at a rate of 112 kbps will be used. Two switched 56 kbps lines will be installed at these communications hubs to provide a cost-effective communications path from the hub to the TOC/TMC. Camera control from the TOC/TMC to the video equipment will also be required. The control will require a low data rate (about 1200 bps) communications link when the camera is active to support camera positioning (pan, zoom, etc.).

8 Agency Considerations

8. AGENCY CONSIDERATIONS

8.1 INTRODUCTION

This chapter focuses on the roles of the local and regional agencies in the implementation of IVHS programs in Orange County. The roles are identified in terms of:

- Establishing a structure for supervision of IVHS improvements
- Determining forums for interagency coordination
- Establishing responsibilities for coordination staffs
- Identification of formal interagency agreements
- Definition of agency responsibilities in development, implementation and operation of IVHS elements

The Chapter will emphasize the importance of good working relationships and the development of a strong interagency structure which can supervise the development of projects, that are fundable and can be successfully implemented.

8.2 IVHS AGENCY STRUCTURE

8.2.1 - Need for an IVHS Agency Structure

In order to achieve the overall objective of improving the County's transportation network through the efficient, effective implementation of IVHS strategies, and maintain a balance between the local and regional needs of the transportation network, it is recommended that a formal structure for the development, implementation, and management of IVHS activities be adopted by the Orange County agencies.

8.2.1 .l - Multi-Agency Considerations

One characteristic of the proposed Orange County IVHS Network which deserves special consideration is its multi-agency aspect. To a great extent, the success of the project will be dependent upon all of the agencies successfully operating with a project environment where, at any given time, multiple interests and concerns may exist and even conflict, This can make decision making a particularly onerous task

The success of the IVHS programs will depend on the continued efforts in development of a consensus between the many agencies which make up Grange County. One such consensus in the past has been for a program to support improved arterial signal synchronization and the establishment of a Signal Roundtable to address various operations and maintenance issues. For the IVHS Programs, the consensus developed by the agencies will be a significant aid to developing programs that can be funded with sources from outside the County. The Federal Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 considers the multi-agency aspect of projects to be a major criteria for funding.

The working relationships established through GMAs and the Signal Roundtable in Grange County are invaluable in balancing various agency interests and concerns. An overriding issue is always the threat to local autonomy when regional agencies are involved in projects with local agencies. Maintaining the balance of the interests through the prompt addressing of such local concerns is crucial. Such concerns need to be dealt with as they arise and not be allowed to build up and create barriers. The success of the M-IS programs will depend on the agencies not only getting the opportunity to express their concerns, but also be presented with a further opportunity to discuss the analysis prior to recommendations being made. often, involvement in the decision making process nurtures support of the decision.

8.2.1.2 - Requirements

The basis for the recommended structure is the need to:

- Provide a forum through which local agencies can work together to develop subregional objectives and programs which benefit the individual agencies together with the subregion.

- Provide the structure through which subregions can stay abreast of the priorities and developments within the other subregions of the County and can coordinate with these other subregions.

- Maintain an avenue through which the local agencies, and their respective subregions, can actively participate in regional decisions regarding IVHS programs in a manageable fashion.

- Provide a structured means through which the numerous state, county, regional, and local agencies can develop and implement coordinated programs.

- Provide an administrative structure through which support (e.g., technical, staffing, equipment) can be disseminated to the local agencies.

- Provide the administrative structure necessary to effectively and efficiently implement large-scale programs such as those recommended by this IVHS Study and those which may be recommended by the County's agencies.

8.2.2 - Maintaining Jurisdictional Responsibilities

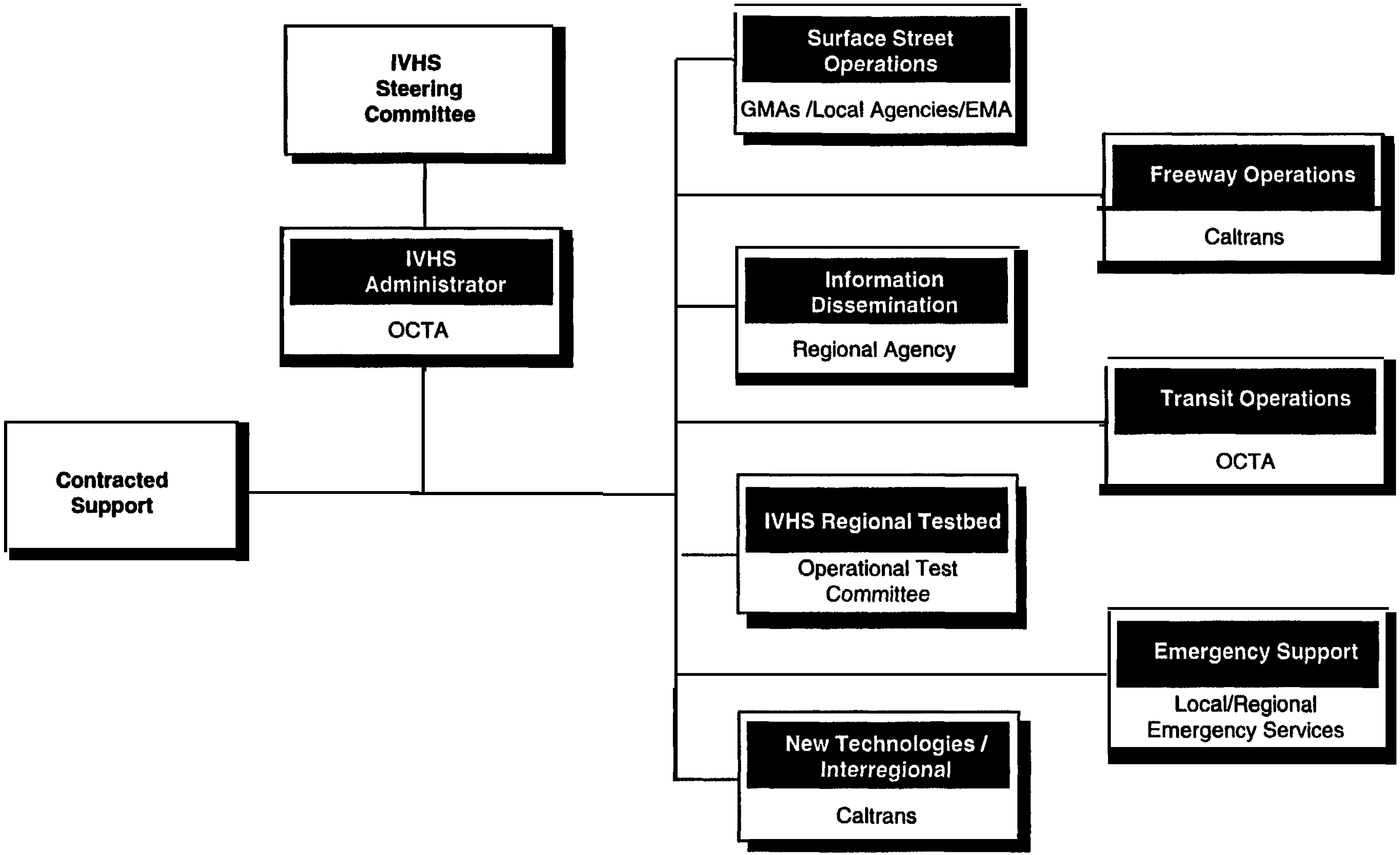
Many of the primary roles of the County's transportation agencies have been defined through their jurisdictional responsibilities. For example, Caltrans operates the County's freeways and local agencies operate the arterials which are located within their boundaries. These roles and responsibilities will remain intact unless other agreements or contracts are entered into by these agencies. It is foreseen that with the implementation of IVHS technologies on the County surface streets, that local agencies may develop multi-agency agreements for the implementation, operation and maintenance of traffic signals, changeable message signs, CCTV, etc.. It is further foreseen that these sub-regional agreements may be entered into under the structure of the designated Growth Management Areas (GMAs).

The recommended IVHS Agency Structure which preserves these jurisdictional responsibilities and addresses the structural issues stated above, is presented in Exhibit 8.1. Below is a discussion of the new roles the various agencies will adopt within this structure.

8.2.3 - Growth Management Areas

As was stated above, the County's agencies must maintain their jurisdictional responsibilities. However, the nature of IVHS requires a great deal of coordination between geographical neighbors and between agencies controlling various intersecting transportation

Exhibit 8.1
IVHS AGENCY STRUCTURE



8.2.4 - Information Dissemination

A regional agency (e.g., OCTA, Caltrans) will be responsible for the Traveler Information Center (TIC) and will serve as primary coordinator of day-today activities involving the automated dissemination of traveler information The Center should be located in a geographically central location to the various transportation agencies within the County as this will decrease the communications costs of linking these agencies to the Traveler Information Database.

It should be made clear that management of the TIC involves no traffic operations functions. This is solely an information dissemination function. Additionally, while logistics requires that a single agency coordinate the activities of the TIC, the Center has been conceived and will be designed to support the needs of the entire County. Also, the TIC activities must be coordinated with other IVHS programs within the County. Thus, the IVHS Administrator will coordinate with the TIC agency, and the TIC agency will report to the IVHS Steering Committee regarding TIC matters.

8.2.5 - IVHS Administration

As stated above, there will be substantial administrative responsibilities associated with implementation of IVHS strategies together with support of the County's subregions. It is recommended that an IVHS Administration Staff be identified to support the County's IVHS program. The responsibilities of this staff would include, among other things:

- Coordinating with GMAs
- Providing Meeting Secretarial Services to the GMAs and Regional Agencies as needed
- Maintaining Draft Agreements
- Coordinating Regional Identification and Formulation of Projects
- Identifying and Pursuing Funding Sources
- Coordinating Projects

It is recommended that a permanent staff would best suit the needs of the County. The advantages of guaranteed staffing and benefits of working with an existing, structured

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- coordinating Projects

It is recommended that a permanent staff would best suit the needs of the County. The advantages of guaranteed staffing and benefits of working with an existing, structured organization will help ensure that the County's directives are fulfilled.

Additionally, OCTA is an ideal agency to act as IVHS Admkktrator OCTA will be coordinating much of the funding and is the one agency with legislated responsibility for the entire County transportation system. Therefore, it is recommended that the OCTA serve as the IVHS Administration Staff for the County.

8.2.6 - Contracted Support

While it is recommended that the IVHS Administration Staff be permanent OCTA staff, it is recognized that this staff may not be able to meet all the needs of this regional IVHS coordination role. Therefore, it is foreseen that there will be a need for support services to be contracted by the Administration Staff on an as-needed basis.

8.2.7 - IVHS Steering Committee

It is recommended that the IVHS Steering Committee represent state, regional, and local agencies together with the private sector (i.e., the Auto Club) and that the group hold monthly meetings open to the public and actively solicit further participation from the private sector. The proposed membership of the committee includes:

Two representatives (one technical [i.e., TAC] and one policy [i.e., Signal Roundtable] level) from:

- Caltrans District 12
- North West GMAs (GMA 1, 2, and 6)
- Central GMAs (GMA 3,7, and 8) - Triangle of PCH, Route 22, Route 55
- South East GMAs (GMA 4,5,9,10, and 11) - south and east of Route 55

Additional single representatives will be provided from:

- OCTA (streets & roads)
- OCTA (Transit)
- OCEMA

- CHP
- Auto Club

The total number of representatives on the M-IS Steering Committee will be thirteen. It is recommended that the six City/County representatives from the GMAs rotate on a regular basis.

The role of the MIS Steering Committee will be to define M-IS Policy and direct IVHS improvements. It is recommended that the Steering Committee be assigned this responsibility to ensure that a multi-agency committee oversees this area of transportation which will affect each of the agencies represented on the committee. This is preferable to having a single agency responsible for the direction The IVHS Steering Committee will direct the development of IVHS in the County with staff assistance provided to the Committee by the IVHS Administration Staff.

The IVHS Steering Committee' s responsibilities will include, but not be limited to, directing the IVHS Administration Staff to:

- Identify Future Programs and Modifications to Master Plan
- Secure Funding
- Implement Programs
- Provide Technical Support
- Develop Traffic Response/Incident Management Plans
- standard setting

As the directing Committee, the IVHS Steering Committee will have final responsibility for the above items. Therefore the responsibilities below are described as duties of the Steering Committee, although it is foreseen that the IVHS Administration Staff will perform the majority of these tasks under the Steering Committee's direction

It should be noted that the IVHS Steering Committee will have no operational responsibilities. Additionally, as all OCTA staff are ultimately responsible to the OCTA Board of Directors, it is recommended that the representative from OCTA on the IVHS Steering Committee act as a liaison between the IVHS Administration Staff and the OCTA Board of Directors, thus minimizing any potential conflicts.

8.3 INTERAGENCY AGREEMENTS

Coordinated traffic response plans and incident management, together witb the possibility of cooperative local traffic operations, requires that uniform standards of operations and maintenance be established. This need includes standardizing cooperative agreements between neighboring jurisdictions. Included in this section are sample draft agreements, based on examples of draft agreements currently in use between agencies, for traffic signal operations and maintenance.

8.3.1 - Memorandum of Understanding

Agencies may wish to provide a "show of good faith" for participation in a multi-agency project at the outset of that project and prior to more formal agreements being established. A Memorandum of Understanding (MOU) is a non-biding, non-legal document which provides this show of good faith. Appendix B-l is an example of an MOU.

8.3.2 - Draft Agreements

No single set of agreements will meet all the needs of every local jurisdiction. The sample agreements included in Appendix B-2 are meant to be used as guidelines for agencies in preparation of individual guidelines to meet the needs of a particular situation Draft Agreements have been prepared for signal operations and maintenance as follows:

- Generic Operations and Maintenance Agreement
- Signals Maintenance (General)
- Signals Operations - Joint Operations: Agency B signals under Agency A signals
- Signals Operations - Coordinated operations under a multi-agency project
- Resolution on the Use of a Common Time Reference

Similar agreements can be executed for the operations and maintenance of other IVHS technologies such as CMS, HAR, CCTV, etc..

8.3.3 - Joint Powers Agreement

Agencies may wish to consider using a Joint Powers Agreement instead of using individual agreements between individual cities Appendix B-3 is an example of such an agreement, This type of agreement is executed between multiple agencies for the purpose of providing a framework to achieve common objectives and assist in the process of establishing more formal, individual agreements. A Joint Powers Agreement differs from an MOU in that it is a biding agreement.

Appendix B-3 presents two Joint Powers or Cooperative Agreements. The first is Cooperative Agreement format which was executed by Caltrans District 12 and the City of Anaheim for the Katella Avenue Interjurisdictional Coo&nation Project, the second is a Joint Powers Agreement between the County of Los Angeles and a number of Los Angeles County cities.

8.3.4 - Caltrans Letter

Appendix B-4 includes a letter from the Software Development and Traffic Control Systems Branch of Caltrans that addresses the question of ownership of software/firmware developed by Caltrans and used at Caltrans maintained and/or operated traffic signals. To summarize the letter, once a local agency takes control of a former Caltrans traffic signal, that agency may not use any Caltrans developed software/firmware in the controller unit unless permission is granted to the local agency, by Caltrans, to use the Caltrans developed software/firmware.

8.4 STAFFING REQUIREMENTS

The nature of the overall IVHS Network for Orange County will be one in which agency operations will be supported through the use of technology. Since most agencies have limited operations staffs, and limited means to expand these staffs, it is proposed that the M-IS Programs be designed so as to improve the quality of information and tools that are available to local agencies using their existing personnel resources. The architecture as presented in Chapters 5 and 7 of this report provides the opportunity to do just that -- improve the quality of information needed to operate a traffic management system under real-time conditions. The architecture will also provide the capability for decision support, in which a proposed multi-agency strategy is developed based on pre-defined requirements by all of the agencies, and can be either implemented automatically or upon approval or confirmation by the local agency.

8.4.1 - Local Staff Requirements

While it is desirable to provide additional staffing at the local level to help improve local-level real-time traffic management, such staffing as a rule is beyond the financial means of local agencies at this time.

However, it is recommended that existing staff who are responsible for traffic control system operation receive the appropriate training and are provided the most current knowledge on traffic management technologies as well as system operations. This support would come through a program administered by OCTA which would provide a necessary level of operations support.

8.4.2 - Environmental Management Agency (EMA)

The above information is also true for Environmental Management Agency (EMA) staff. However, it may be appropriate, given the relative level of responsibility for traffic operations staff, for EMA to assist OCTA directly in maintenance and operation of the system architecture. Specifically, the maintenance of interties between local and subregional nodes and between subregional nodes and the TIC may be an appropriate responsibility for EMA. The agency has been developing a program in which coo&nation of local agency signal operations and sharing of data is accomplished through a means similar to what has been described in this study.This is also true for the agency' s own traffic signal systems in unincorporated areas and in Cities to which EMA is contracted to operate signals. Therefore, such a role in the overall IVHS Architecture would be appropriate for EMA.

In this regard, it is recommended that EMA be responsible for maintenance of the local and subregional interties, and to coordinate and maintain any interagency hardware not owned by the local agencies. It would be expected that coordination would be accomplished through existing in-house staff, with contracted maintenance personnel utilized through an on-call contract.

8.4.3 - Information Dissemination Staff Requirements

The regional agency responsible for dissemination of transportation information throughout the County and neighboring areas, will require staff to fulfill this role. This staff, which is identified below, may require new staff hirings, contract staff, or reassignment of existing staff.

8.4.3.1 - Manager of Traveler Information Center

The Manager of the Traveler Information Center (TIC) would be responsible for managing the real-time operation of the various centralized IVHS functions at the TIC. These include the maintenance of the Traveler Information Database and dynamic exchange of information between agencies, the dissemination of data through various subsystems, including cable television servers (one per cable franchisee), the interactive media and public interfaces (including bulletin boards and kiosks), dial-up phone services, plus other agency-operated elements.

In addition, the Manager would also be the primary coordinator between the IVHS Steering Committee and third-party and private-sector disseminators of data who would maintain data servers at the TIC, including in-vehicle information systems, stand-alone and portable information systems, and other strategies.The Steering Committee would set dissemination policies. The Manager of the TIC would coordinate with the IVHS Administrator and Steering Committee on any agency-related improvements that may be required in order to expand the operational or communications capabilities of the TIC, in support of local or regional real-time transportation management, as well as to support additional third-party users of traveler information.

The TIC Manager would likely have 5 or more years of experience in traffic operations, with a primary background in computerized traffic management systems, as well as a background in IVHS technologies.

8.4.3.2 - Information Svstem Specialist

Depending on the extent of private-sector participation, it may be desirable at a later date to provide an Information System Specialist (ISS) to assist the Manager of the TIC. His/her activities would involve technical liaison with private vendors and set-up of third-party-provided dissemination tools and servers at the TIC, including interface with the Traveler Information Database.

The ISS would have a primary background in the area of computer systems and network operating systems, as well as a background in software development and maintenance.

8.4.4 - Caltrans Staff Requirements

In the case of Caltrans District 12, a detailed staffing requirements analysis was performed as part of the Orange County Traffic Operations Center Study in 1991, and it is not expected that the additional elements provided as part of the County's IVHS programs would require additional staffing. However, in terms of institutional issues, Caltrans has stated they will address any joint Caltrans - local agency issues through the use of a dedicated agency liaison, whose intent would be to work with local agencies on resolution of various interagency policy issues involving traffic operations on freeways and adjoining surface streets. It is recommended that this liaison be a member of the IVHS Steering Committee along with the appropriate Caltrans policy representative, and that this liaison be in close contact with the GMAs.

8.4.5 - OCTA Staff Requirements

For OCTA, which would administer, under the guidance of the IVHS Steering Committee, the various IVHS Programs in the County, several functional responsibilities will exist.

OCTA will require staffing support in each of the following areas:

- Administration and Funding of IVHS Programs in the County.
- Liaison with Private Sector Information Services or Vendors
- Maintenance and Technical Support for OCTA-owned and local-agency based equipment where additional support and training of local staffs is required

JHK proposes that OCTA maintain the following IVHS Administration Staff, either through new hirings, contract staff or through reassignment of existing staff.

8.4.5.1 -IVHS Administrator

The IVHS Administrator would be responsible for administration of all IVHS Programs. This includes being the primary contact person for all the agencies with respect to IVHS and interagency traffic management programs and infrastructure currently in place or proposed The work includes obtaining the necessary funding, preparing Request for Proposals (RFP) and Bid Documents, and coordinating agency and public-private partnerships as necessary to implement the specific programs or program elements. The IVHS Administrator would also be responsible for maintaining and updating the IVHS Master Plan and GMA/Sub-regional Action Plans as necessary to reflect changes in available technologies and the means of implementation, as well as changes in funding.

The IVHS Administrator would have a minimum of 10 years experience in program management, including management of projects specifically dealing with IVHS and traffic management improvements. He/she would also have substantial background in development of local roads and/or transit funding programs. Additional experience in the area of traffic operations would also be desirable.

8.4.5.2 - IVHS Technical Liaison

The purpose of the IVHS Technical Liaison is to provide local and other agencies with technical support and information which will assist the agencies in the area of operation of their facilities. The technical liaison would oversee any maintenance support activities required of the agencies as a result of any upgrade or expansion of their traffic management systems in conjunction with IVHS Programs developed through or consistent with the County's IVHS Master Plan The technical liaison would also work with the agencies in developing programs which would enhance their transportation systems using IVHS technologies, and would coordinate with the IVHS Administrator in developing the programs on the local level.

This technical liaison would have at least 5 years experience in the various technical areas of IVHS and traffic management systems, and be familiar with the various traffic management programs and funding sources available to the agencies.

8.4.5.3 - IVHS Maintenance Support

Maintenance support personnel would include one to two people, who would assist all agencies in the County with maintenance of their traffic management systems on an on-call basis. The support personnel would also assist OCTA on maintenance of in-house equipment. The maintenance support staff would consist of personnel with electronics and computer experience as well as experience in the area of on-call support and maintenance of field elements (e.g., traffic signals, changeable message signs, controllers), as well as central elements (computers, software, peripheral equipment, network operating systems). The support personnel would assist the EMA and local agencies in maintenance of communications systems, including fiber optics, twisted-pair, microwave, spread-spectrum, and other technologies. The EMA would retain responsibility for maintenance of the interagency communications interties, while the appropriate local agency or Caltrans would be responsible for control-to-field communications.

Given the highly specialized nature of the above requirements, as well as the highly operations-oriented nature of this work, it is unlikely that OCTA currently has the existing staff with the diversity of background required for this work It is therefore recommended that new staff be added or that the work be contracted to a system or consultant with the necessary background in the above elements.

9

The Master Plan

jhk & associates

9. THE MASTER PLAN

9.1 INTRODUCTION

In this Chapter, specific programs for implementation within the Orange County IVHs Network in Grange County are defined. These programs have been identified based on the following considerations:

- User services developed from the overall goals and objectives defined for the transportation network
- IVHS and related elements to carry out the functional strategies and techniques defined to meet the overall goals and objectives
- The structuring of a county-wide IVHs network based on the linking of autonomous agency elements into an integrated system for traveler information and transportation management
- Development of enhanced interagency relationships through existing means such as Growth Management Areas (GMAs) as well as through development of defined traffic management corridors (e.g., Smart Corridors, Smart Streets)
- Providing enhanced support to local agencies in maintenance and upgrade of local traffic management systems

The programs are presented in this section in terms of their elements and with brief descriptions which are meant to guide further development and design of the programs. As is explained in the descriptions, many of the items are codependent. For example, development of "Traveler Information" elements requires programs to enhance "Monitoring and Data Collection" Such dependencies will be discussed here, and incorporated into the development of the IVHS Action Plan being submitted with this report.

It is emphasized that this IVHS Master Plan for Orange County will be dynamic and flexible, adoptable to emerging technologies and evolving public and political acceptance and support of IVHS.

9.1.1 - User Services

In the course of this IVHS Study, the Federal Highway Administration (FHWA) has developed a series of User Service categories to be used as a guide in the development of IVHS strategic plans. These categories have been defined as follows:

- Traveler Information
- Traffic Management
- Public Transport and Emergency Vehicle Management
- Freight and Fleet Management
- other services

The descriptions of these User Services essentially correspond to the definitions for the "traditional" IVHS categories--traveler information parallels ATIS, traffic management encompasses ATMS, and so forth. However, the user service categories have been defined to be functional in nature: no references to the technologies required to achieve these services has been made.

Although these categories represent a highly useful overall definition of IVHS services in general, it was determined that a better definition of the program areas needed for Orange County was required. In particular, a key emphasis in Orange County is on the support of Travel Demand Management (TDM) policies. To this end, the proposed IVHS elements involve the development of enhanced real-time information on transit services, improved information on ridesharing and improved transit management. Elements of these functions would be integrated with traffic management and traveler information systems. This would allow for multi-mode traveler information readily available to the public as well as a broader base of information for use in overall transportation management. This information base is also useful in the planning and analysis for future improvements through the County's Congestion Management Program (CMP).

The program areas as applicable to Orange County were defined as follows:

- Traveler Information
- Monitoring and Data Collection
- Traffic Management

- Transit and High-Occupancy Vehicles (HOV)
- Automated Vehicle Control

The first three areas are relatively self-explanatory. The Transit/HOV programs refer to any transit fleet management or ridesharing elements which can be used to enhance TDM policies and assist in reducing the dependency on Single-Occupancy Vehicles (SOV).

For Automated Vehicle Control, it is expected that such elements would be initially incorporated as part of the overall transportation infrastructure toward the end of this study's 20-year timeframe. Nevertheless, it was determined that certain automated control elements will become reality on an autonomous (in-vehicle) basis much earlier, and that certain information may be required within the vehicle to implement these controls. For example, the use of automated cruise control devices may depend on knowledge of downstream traffic conditions as well as the use of the appropriate in-vehicle sensors which can identify the distance from a vehicle traveling in front. Thus, the other programs would be expected to provide a significant portion of the information and the infrastructure necessary for the eventual implementation of certain Automated Vehicle Control strategies.

In the user service area of Freight and Fleet Management, it was determined that the development of Traveler Information and Monitoring/Data Collection programs would support programs that may be developed in the future for freight operation in the County. The Freight and Fleet Management area was not determined to be of substantial concern on a Countywide basis, and it was felt that this is better handled on a larger regional basis.

9.1.2 - Program Definitions

The remainder of this Chapter identifies the IVHS programs to be developed for Orange County. These programs are defined for each user service identified above. Specific elements of these programs are identified along with the agency(ies) which would implement them. In some cases, implementation would be done by several agencies, or through some public-private partnership.

9.2 TRAVELER INFORMATION

Traveler Information programs deal both with provision of information to the public and exchange of information between agencies,and is dependent upon procurement of this information from various agencies as well as Monitoring and Data Collection programs to collect the required information in the field

Exhibit 9.1 identifies the specific programs, as well as their specific elements and agency responsibilities for development. They are further summarized below in terms of specific applications. Also discussed below are the other programs on which Traveler Information is dependent.

9.2.1 - Universal Traveler Information Program (UTIP)

Through this study, development of a County-wide Traveler Information System (TIS) was identified, and has been selected to receive Federal funding for its design as an Early Deployment Project. This TIS would be the basis for a full Universal Traveler Information Program (UTIP), the purpose of which would be to provide the public with information pertinent to making travel decisions for freeways, surface streets and transit.

The Early Deployment TIS would include the following elements:

Traveler Information Database (TID). A central database would serve as a clearinghouse for all real-time freeway and surface street link data, as well as pertinent real-time incident or event information. The TID would also be capable of gathering transit-related schedule and location information The intent of this data would be to serve as a basis for spatially-related dissemination (e.g., map based graphics), text dissemination and audio dissemination.

CATV Video Servers. Video servers would be provided for each cable TV carrier in the County for dissemination of freeway and surface street traffic flows and other pertinent travel information, using color-coded maps updated in real-time.

Kiosks at Transit Centers. Interactive kiosks would be provided at rail-bus transfer locations. The appropriate data servers at the central TID location would be provided

Exhibit 9.1

TRAVELER INFORMATION **PROGRAMS**

Program	Element	Responsibility OCTA	Caltrans	EMA	Loca	Pfivate
Universal Traveler Information Program (UTP)	Traveler **Information Center**	X	X			
	Traveler Information **Database*** (Geographic Information System-Based)	X	X			
	Information Servers for:					
	– CATV Broadcast (Traffic Maps)*	X	X			
	-Local Kiosks at Transit Centers*	X	X			
	- Privately-Funded Kiosks					X
	– Traveler Advisory Telephone	X	X			
	– Bulletin Board Systems"	X	X			
	– In-Vehide Navigation Interface	X	X			X
	– Personal Portable TIS					X
	– Radio Data Systems					X
	– Silent Radio					X
Interagency Transportation Information Exch ange (INTERTIE)	Communioationr Interties*	X	X	X	X	
	Local Node Processors				X	
	Sub-Regional Node Processors (Hubs)			X		
Interactive Travel Infromation Kiosks [KIOSK)	Kiosks at Transportation Centers*	X			X	
	Kiosks at Public Events Centers	X			X	
	Kiosks at Privately-Owned Facilities					X
Public Information Campaign	**Public Relations/ In-House or** Consultant	X				
Freeway Motorist Information Systems (FMIS)	Full-Matrix CMS		X			
	Low-Power HAR		X			
Arterial Motorist Information Systems (AMIS)	Full-Matrix CMS			X	X	
	Trailblazer CMS			X	X	
	Mobile CMS	X		X	X	
	Low-Power HAR			X	X	
In-Vehicle Information Support infrastructure for On-Street Navigation (INVISION)	In-Vehicle Devices					X
	Data Server	X	X			X
	Communications Llnks / Vehicle-Roadway end Roadway-Centrd		X	X	X	X

if more then 1 Responsible Agency/Entity Shown, Element Assumed to be **Multi-Agency** or Public-Private Partnership

I Partially Implemented Through Early Deployment Project

Bulletin Board Servers. Interactive bulletin boards would have access to map-based travel information using the appropriate data server to be provided at the central TID location.

Other Elements. The Early Deployment elements of the TIS would include up to two communications interties (TIC-Santa Ana and TIC-Irvine) in addition to an intertie with the City of Anaheim installed under an Operational Test project. The TIS would also include approximately 200 surface street detection sites which would contribute to the distribution of traveler information.

The UTIP would include, over and above the Early Deployment TIS, the following elements, for which a preliminary design and requirements analysis would be conducted as part of the Federally-funded Early Deployment project design:

Traveler Information Center (TIC) . A central location for all traveler information dissemination elements would be provided at a regional facility. This facility would include the Traveler Information Database, a User Workstation for operator monitoring of overall system operations, and all data servers and communications equipment necessary for gathering and disseminating traveler information.

Traveler Advisotv Telephone (TAT). A county-wide travel information service would be available free of charge through the use of a multiple-line phone system with the capability of touch-tone selectable route travel information. The information would be synthesized through the use of digital voice techniques provided through a voice-response system (VRS). The VRS would automatically scan TID information and present it in a deliverable format.

Other elements that would be part of the UTIP would involve public-private partnerships for implementation due to the lack of standardization of a number of the elements, or due to expected funding constraints. These other elements include:

Information Servers. These would involve servers for privately-funded or privately-developed devices, for which the private developer would define his information needs and a server would be utilized to pull information from the Traveler Information Database and put it into a format to be disseminated to the devices. Such a format would require some communications configuration for wireless transmission to the field or to the public. It is expected that standardization of data format and communications protocols over wireless media would reduce the number of required servers. At this time, it is forecast that a different server would be required for each type of information to be disseminated. Expected servers include:

- Privately-Developed Kiosks and Information Systems Located at Traffic Generators and Event Centers
- In-vehicle Information and Navigation Devices
- Personal and Portable Information Devices, including hand-held programmable devices. These may include specially-developed devices (purpose-built, proprietary), or they could use palmtop or Personal Digital Assistant (PDA) devices. Examples include the Sharp Wizard with touch sensitive graphical interface and the Apple Newton.
- Radio Data Systems (Audio and Text data)
- Silent Radio (Text data)

Related programs. As discussed in further detail in the next several subsections, these are to be defined in order to implement the UTIP. These programs include the following:

- JNTERTIE - Development of interagency communications network. (See below)
- INTER-RIDE - Automated rideshare database using interactive information to match up ridesharers. (See Transit/HOV Programs
- Arterial and Freeway Instrumentation Programs - Would result in installation of traffic data stations where necessary as well as installation of Automated Vehicle Location (AVL) devices on fleet and private vehicles. (See Monitoring and Data Collection Rograms.)
- Agency Traffic Operations Support (ATOS) – Detector maintenance programs on a county-wide basis will ensure the accuracy of data provided from freeways and surface streets and disseminated through the UTIP elements. (See Traffic Management Programs)

9.2.2 - Interagency Transportation Information Exchange (INTERTIE)

This program will develop the infrastructure of interagency communications links required for the development of a County-wide IVHS network, in particular the sharing of information between agencies and development of a common Traveler Information Database (TID) as discussed above.

This infrastructure would be based on the need for standardized communication links between agencies and the development of node processors which are developed at the local and subregional (i.e., Growth Management Area [GMA]) levels to communicate with existing or upgraded local traffic control systems. The INTERTIE would include the following:

> Local Node Processor. It is proposed that a node processor be developed for each agency or group of agencies utilizing a single traffic control system. The intent of this node processor would be twofold: to collect data from neighboring traffic management systems and from the freeway/toll road network, and provide it in a manner such that the data can be displayed for use in assessing traffic management strategies, or can be utilized in an automated fashion to implement specific traffic management strategies.
>
> Subregional Node Processor. For a group of several traffic management systems within a GMA, a subregional hub is proposed for the purposes of data distribution within the GMA and developing a common, multiplexed data link from each group of systems to the Traveler Information Center at OCTA. This configuration would reduce costs for implementation of the communications network, and would increase the flexibility of data sharing and expansion of system elements. The subregional processor would provide the primary direction of data collection for Smart Corridor operations, as the Smart Corridor Expert System and user elements would be located on the local and Caltrans levels.
>
> Communication Interties. These would consist of appropriate communications links between local agencies and subregional hubs organized loosely based on GMA boundaries. One hub per GMA would be provided and communication links from each GMA area would then serve the Traveler Information Center at OCTA.

The above network elements would have the following characteristics:

- Data links using TCP/IP or other standardized protocol
- Video links using a standard wideband protocol such as NTSC RS-170 where video capabilities are available

9.2.3 - Interactive Travel Information Kiosks (KIOSK)

This program would consist of providing the means of disseminating traffic and transit data to the public at transportation, employment and event centers, through the use of interactive user terminals, or kiosks. As many of these kiosks would be located in privately-owned or operated facilities, it is desirable that full implementation of this program be accomplished through a combination of public and private funding. This would be divided as follows:

- Rail-Bus-Auto Transfer Terminals (e.g., Rail Stations, Transportation Centers) -- OCTA-funded.
- Publicly-owned facilities, (e.g., stadiums, arenas, fairgrounds) -- Funding by OCTA and owner of the facility.
- Privately-owned and operated event centers, employers, commercial facilities -- Private funding with coordination with OCTA.

A key element in the development of the above kiosks will be the desired information to be presented to the public. For example, the kiosks at transit centers may be oriented specifically to transit information, while kiosks at event centers may provide some combination of traffic and transit information as selected by the user.

9.2.4 - Public Information Campaign

The media is one of the most effective and established advanced technologies available and as such is a key element to the success of the County IVHS network. The media should be used for two purposes: first, to develop political and public awareness of the importance of traffic management and the resultant benefits, and second, to encourage motorists to do their part to decrease traffic turbulence. It is proposed that OCTA, either internally or through a contractor, develop an appropriate public information campaign.

It is widely known among traffic engineers that traffic signal coordination efforts are relatively inexpensive compared to the benefits derived from it in terms of reduced delay and vehicle emissions. It is necessary for the politicians and the public who control the purse strings supporting such efforts to be made aware of these benefits. Additionally, as IVHS improvements are made, the public should be informed of their intent and their potential benefits. (This will be especially important as traveler information systems are implemented throughout the County.)

Similarly, it is known that a short duration of turbulence in traffic can have much longer-lasting effects on congestion Often, a commuter may be slowed due to congestion which develops behind an incident, only to find once they reach the area where the congestion initially occurred, that there is no incident. The delay which results from incidents and other causes of traffic turbulence can be reduced through modifications in driver behavior. This can be accomplished through a public campaign similar to the "Conserve Water" campaign which has been predominant on the radio during the last few years of drought. In addition, assistance from related agencies such as the Auto Club and Transportation Management Associates (TMAs) can be enlisted.

9.2.5 - Freeway Motorist Information Svstems (FMIS)

This program incorporates elements presented in the Caltrans District 12 TOS Master Plan which provide motorist information along freeways. Those specific elements of importance to the IVHS Network include the following:

Full-Matrix CMS. Full-matrix CMS are to be installed one exit in advance of freeway-to-freeway interchanges along the network, and in other locations as required for traffic management, including Smart Corridor operations.

Low-Power HAR. Synchronized, low-power HAR transmitters, developed in a linear zone configuration, allow roadway-specific traveler information to be presented. A disadvantage of the current lo-watt HAR technologies is that, while it has a greater listening range, the information presented may not be relevant to all motorists in the corridor, nor can it be specific regarding advisory messages. Low-power HAR transmitters provide more focused coverage, such that real-time, specific motorist advisories relevant to that roadway can be presented without additional information not relevant to the motorist As such, low-power HAR is useful to implement real-time Smart Corridor operations strategies, which involve specific exit ramps and freeway links.

Low-Power HAR is thus proposed to supplement the proposed High-Power transmitters in the TOS Master Plan along those freeways that are part of Smart Corridors.

A coordinated approach to HAR frequency definition will be required. Current FCC guidelines do not provide dedicated frequencies for Traveler Information. Therefore, coordination at the regional level is required to assure that 10-watt and low-power HAR frequencies do not overlap, nor do they interfere with other broadcast frequencies.

9.2.6 - Arterial Motorist Information Systems (AMIS)

Similar to the freeway elements presented above, this Master Plan recommends a number of similar elements be implemented along major portions of the arterial network. The specific roadways for implementation of each of these elements have been identified in Section 2. These locations include arterials within Smart Corridors, designated Smart Streets and other arterials of regional significance, and other locations as identified by local agencies.

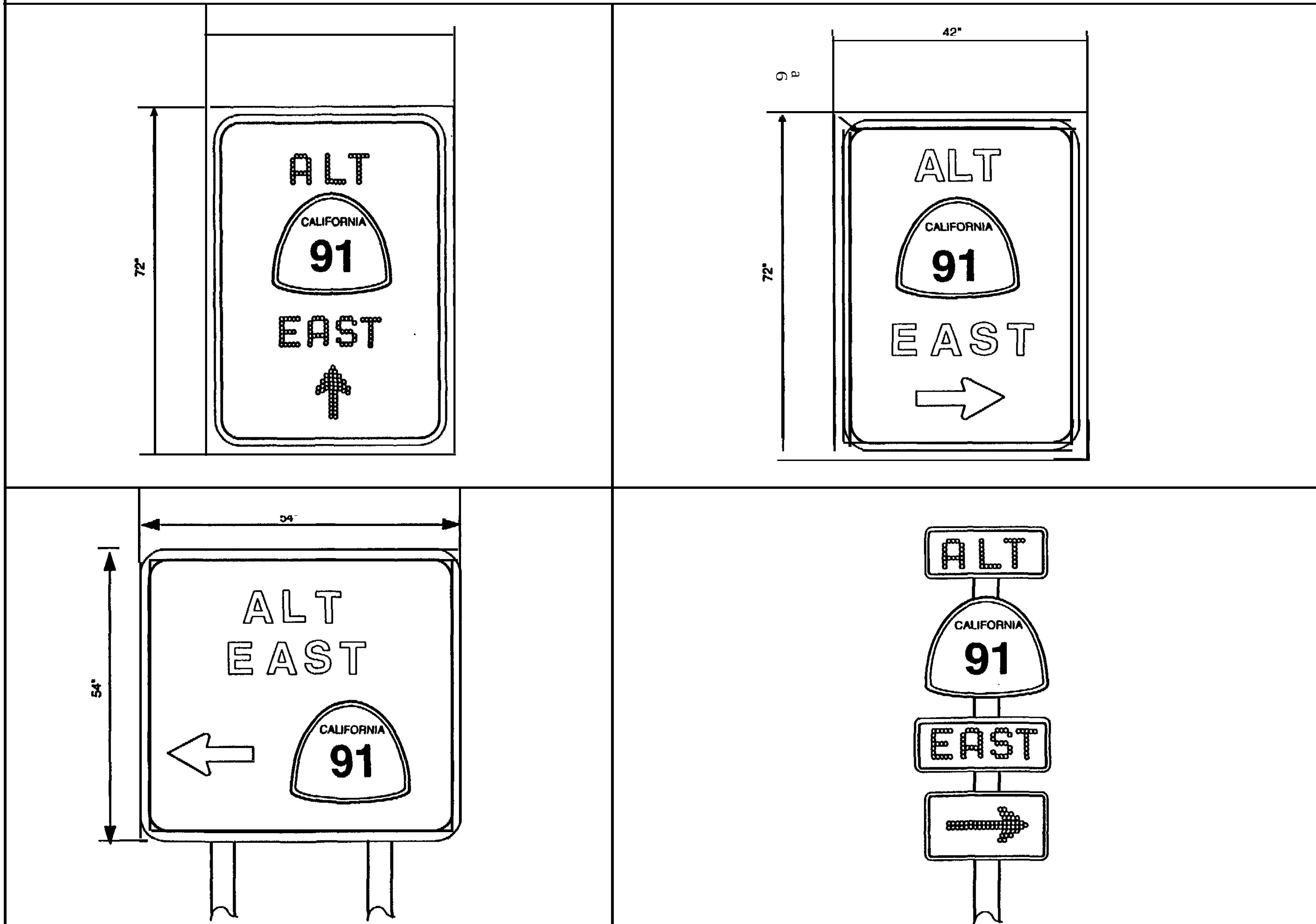
Full-Matrix CMS. On arterial routes, full-matrix CMS are to be installed on designated Smart Corridor roadways perpendicular to the primary corridor direction, in advance of arterial routes parallel to freeways. The purpose of the signs is to identify specific congestion or incidents on the freeway, such that appropriate decisions regarding freeway access can be made by the driver. As necessary, advisory information is provided which identifies a required freeway alternate. Full-matrix CMS can also be used on non-Smart Corridor arterials where frequent special events require regular sign messages providing access or parking information.

Trailblazer CMS. Trailblazer signs are installed in advance of intersections between Smart Corridor arterial routes parallel and perpendicular to freeways. The purpose of these modified route trailblazers is to provide positive route guidance information (see Exhibit 9.2) around a section of freeway which is affected by unusually heavy congestion or a major incident.The intent is to direct local traffic to the most appropriate freeway entrance, and to guide freeway traffic which has chosen to divert due to a lane closure or incident. This guidance would have the impact of keeping unfamiliar and non-local traffic only on acceptable routes, thus minimizing the impacts of freeway incidents on local traffic flow.

Mobile CMS. The purpose of these portable CMS devices is to provide specialized access, parking and routing information for seasonal or short-term events. Such signs would be maintained in a pool arrangement through OCTA,

Exhibit 9.2

TYPICAL TRAILBLAZER LAYOUTS



in which agencies would utilize the number of signs necessary to implement a short-term traffic management plan for a specific event They would also be available for use under emergency situations, where the use of CMS would assist in providing positive guidance for an emergency routing strategy.

Low-Power HAR. The use of low-power HAR transmitters, as discussed for freeway MIS elements above, is desirable for presenting information targeted at a specific group of motorists. It is recommended for installation along Smart Corridor roadways. Typical transmitter spacings are l/4 mile, but may vary depending on advances in equipment and the topology of the broadcast area. Low-Power HAR is most effective when automatically operated using a Voice-Response System (VRS) to develop digitized messages based on automated querying of the Traveler Information Database concerning incidents and events, and the resulting traffic conditions.

9.2.7 - In-Vehicle Information Support Infrastructure for On-Street Navigation (INVISION)

A major IVHS element is the in-vehicle navigation and information device. These systems provide motorists with real-time traffic information and can select optimal routes based on motorist inputs to the system, such as origin and destination. The instrumentation of the IVHS Network under the Monitoring and Data Collection Programs will provide much of the necessary support for this program in terms of the sources of information. A number of vendors are developing in-vehicle systems featuring fixed-time travel information, with two experimental systems in the US, TravTek (Orlando, Florida) and Pathfinder (Los Angeles) having the capability of accessing real-time traffic information. It is expected that standard&d industry communications protocols and techniques would allow a variety of different systems to access the same travel information.

The IVHS Network infrastructure is to support the development of in-vehicle navigation through the development of proper vehicle-roadway and roadway-central communications links. It is proposed that implementation be done through a public-private partnership arrangement. In particular, vendors which would like to implement their products in Change County should be willing to contribute to the cost of developing the vehicle-roadway and roadway-central links. This is particularly true if industry-wide standards for such links are not developed in the immediate near-term, and competing systems are implemented side-by-side.

In-Vehicle Devices. These are being developed by third-party vendors, and should not involve any investment by the public sector.

Data Server. The data server for in-vehicle navigation would access the Traveler Information Database and send the data over the defined communication links. The server would either be "universal" (if standard&d protocols are developed industry-wide) or would be proprietary to the specific in-vehicle system developed. If one or more proprietary systems are developed, it is proposed that private funding be used for provision of the data server(s).

Communications Links. The INVISION program will include development of vehicle-roadway links and trunk distribution links, to allow transmission of traveler information to motorists with in-vehicle navigation devices, and also allow vehicle location and identification to be transmitted back to the TIC.

Vehicle-roadway links may include the use of regularly-spaced infrared beacons and low-power two-way radio transmitters, such that data could be exchanged to and from the trunk communications distribution network. Such links would be wireless in nature, and would be based on standard protocols and interfaces. These protocols and interfaces would be based on industry standards that are developed in the next several years.

Roadway-Central links would be expected to utilize fiber optics trunk facilities being developed by Caltrans for their TOS, but may also involve additional links using lower cost elements, including dedicated leased lines, microwave, or spread-sprectrum radio.

9.3 MONITORING AND DATA COLLECTION

The programs developed for monitoring and data collection will serve two key functions. One of these functions is to provide real-time information for use by agencies and by the public. A second function is to provide a source of data for the planning and analysis of proposed transportation programs, including Congestion Management Plan (CMP) strategies.

Two types of quantitative information will be obtained from the network One type will be "floating" information available through Automatic Vehicle Location (AVL) techniques, which will provide probes throughout the network for dynamic travel data measurements and origin-destination analyses based on the samples. A second type of information will be the more conventional point-based information, as developed through system detection locations which .

provide volume, congestion and speed data at a single location. In addition, incident detection may be accomplished through the use of appropriate algorithms to compare between adjoining stations or assess temporal traffic flow changes at a single location point.

Monitoring and data collection can also involve the use of qualitative information. The use of Closed-Circuit Television (CCTV) cameras provides the opportunity to confirm information obtained through quantitative means, and to verify the impacts on changes in traffic management strategies.

The use of Video Image Processing Systems (VIPS) allows a combination of quantitative and qualitative monitoring and data collection strategies, with VIPS providing an added dimension of measuring specific visual (two-dimensional) character&tics to assess specific conditions, including the presence of an incident.

The following programs are proposed below, and are illustrated in Exhibit 9.4 in terms of recommended agency responsibilities regarding installation and implementation.

9.3.1 - Automated Vehicle Location (AVL)

The development of AVL will include the implementation of appropriate geographic-based tracking software at the TIC, as well as installation of probes in vehicles.

Transit Fleet AVL. Initially, it is proposed that AVL be installed in transit vehicles as an information input to the transit information system elements to be proposed as a part of the Transit/HOV Programs presented later.

Public Fleet AVL. This includes the use of AVL in public fleets including police and fire vehicles, as well as other agency vehicles. These would provide assistance in determining location and estimated time of arrival for specific incidents, and for agencies which develop their own AVL systems, assist in tracking of their own vehicles.

Private Fleet AVL and AVL in Private Vehicles. This application of AVL would involve the traveling public, and might involve company fleets, or fleets of rental vehicles. These would provide the best potential representation of how “normal” traffic behaves, since these vehicles would not be constrained by routes, schedules, or functions. Funding for AVL at this level would come through the Private Sector’ s provision of such devices, in conjunction with a recognized AVL

Exhibit 9.3

MONITORING AND DATA COLLECTION PROGRAMS

Program	Element	Responsibility				
		OCTA	Caltrans	EMA	Local	Private
Automated Vehicle Location (AVL)	Transit Fleet AVL	X				
	Public Fleet AVL	X	X	X	X	
	Private Fleet AVL					X
	AVL in Private Vehicles					X
Freeway Instrumentation (FI)	System Detection		X			
	CCTV Cameras		X			
	VIPS		X			
Arterial instrumentation (AI)	System Detection			X	X	
	CCTV Cameras			X	X	
	VIPS			X	X	
Detector Maintenance Program	Developed through ATOS Program	X	X	X	X	

interface standard compatible with that used for transit and public vehicles as part of the IVHS Network.

9.3.2 - Freeway Instrumentation

This program incorporates elements presented in the Caltrans District 12 TOS Master Plan which provide instrumentation for monitoring and surveillance along freeways. Those specific elements of importance to the IVHS Network include the following:

Svstem Detection. Loop detectors along freeway and toll road mainlines are to be provided at maximum l/2 mile spacings, including just upstream of ramp junctions. These are connected to the Caltrans TOS, and the resultant link traffic information would be transmitted to the TIC via the interties identified above.

CCTV Cameras. CCTV Cameras are to be provided at freeway interchanges and other locations as identified in the Caltrans TOS Master Plan, to provide the ability to confirm and monitor traffic flow conditions as well as incident conditions.

Video Image Processinn Systems (VIPS). As discussed in the Caltrans TOS Master Plan, a number of locations will be selected for VIPS installation. Where use of this technology is deemed cost effective, it is recommended that VIPS be considered in lieu of system loop detectors.

9.3.3 - Arterial Instrumentation

It is proposed that arterial roadways be instrumented to provide an improved level of information on traffic flow along arterials in Smart Corridors as well as along designated Super Streets and other roadways of regional and local significance. In this Master Plan, a basic level of instrumentation is identified for Smart Corridor arterial roadways and designated Super Streets. It is proposed that the GMAs and local agencies identify any additional roadways in which instrumentation for traffic monitoring and surveillance is necessary or desirable.

System Detection. Loop detectors or other alternative detector technologies are to be implemented along Smart Corridor roadways and designated Super Streets at least 300 feet in advance of intersections which GMAs or local agencies identify as critical, and at maximum l/2 mile spacings between signalized intersections. These detectors would be connected to the local traffic control system, and the resultant link traffic information would be transmitted to the TIC via the interties identified in Section 9.2.2 above.

CCTV Cameras. CCTV Cameras are to be provided at the intersections of primary Smart Corridor arterial roadways as well as at intersections of designated Super Streets with other Super Streets or Smart Corridor roadways. CCTV cameras are also to be installed at high volume intersections adjoining traffic generators and event centers as defined by the local agencies or GMAs. The use of CCTV will provide the ability to confirm and monitor traffic flow conditions and changes to signal timings, as well as incident conditions.

Video Image Processing Svstems (VIPS). Several critical locations are to be selected for VIPS installation. It is recommended that these locations be where levels-of-service currently are at “E” or below. Where use of this technology is deemed cost effective, it is recommended that VIPS be considered in lieu of system loop detectors.

Detector Maintenance. As part of the contracted support services provided by OCTA, a detector maintenance program is recommended and is described in section 9.4.1. This will enhance the reliability and accuracy of the system considerably.

9.4 TRAFFIC MANAGEMENT PROGRAMS

The traffic management functions represent a significant component of the Orange County IVHS Network, as they cover a wide-ranging array of programs which will directly benefit the public through enhanced agency traffic operations capabilities and support of both local and regional operations.

In Exhibit 9.4 and below are listed programs which are both institutional and technical in nature, and will include maintenance elements as well as operations elements. The mapping of specific improvements on roadways will be done as part of the upcoming Action Plan, where the improvements will be prioritized.

Exhibit 9.4

TRAFFIC MANAGEMENT PROGRAMS

Program	Element	Responsibility				
		OCTA	Caltrans	EMA	Local	Private
Agency Traffic Operations Support (ATOS)	OCTA Technical Liason	X				
	Maintenance Support – Signal Operations – Detectors – Other IVHS	 X X X		 X X X	 X X X	
Decision Support Systems	Smart Corridor Expert Systems TOC and TMC's	X	X	X	X	
Emergency Priority System (EPS)	Signal Pre–emption Testbed			X	X	
Rapid Incident Clearance (RIC)	Full Deployment of Freeway Service Patrol (FSP) CHP/FSP Interface with UTIP System	X	X			
	Mobile Data Terminal Interface w/UTIP System	X				
	Accident Investigation Sites		X			
Adaptive Signal Control & Signal Synchronization Program (ADAPT)	Software Development		X	X	X	
	System Hardware Upgrades		X	X	X	
	Field Hardware Upgrades		X	X	X	
Corridor Ramp Metering Strategies	Software Development		X			
	Additional Ramp Meters		X			
Integrated Signal / Ramp Meter Control	Software Development		X	X	X	

9.4.1 - Agency Traffic Operations Support

The introduction of new traffic management elements to local agencies as part of the County's IVHS Network will introduce a number of operational and maintenance issues, of which many agencies may not have the available staffing or the available technical knowledge. As large segments of arterials (Smart Corridor freeway alternate routes and designated Super Streets) are recommended for IVHS field elements, it is expected that groups of cities, or potentially, entire GMAs, will require technical support and assistance in the development, design, and construction of multi-agency improvements. In addition, agencies are looking for assistance in pursuing or developing projects of use to their communities due to the lack of local staff time. Therefore, a Traffic Operations Support program is recommended This program would provide the availability of permanent and contracted staff to assist both GMAs and local agencies in the development of projects as well as the operation and maintenance of various traffic management and other IVHS elements.

OCTA Technical Liaison. The technical liaison will have the responsibility of working with the GMAs and local staffs in development of multi-agency projects for funding through local, State and Federal funding sources. The technical liaison will also work with the GMAs agencies in the development of criteria for evaluation of initial IVHS projects.

Maintenance Support (Contracted). It is recommended that a system of technical support, which includes staff which may be available to support GMA and agency operations on a roving basis, be established.

The function of the technical support and staff may vary across a wide range of fields including items such as advising on signal timing or communications, controller requirements, and providing assistance with preparation of requests for proposals, identifying funding opportunities, and preparing proposals for funding. A logistical restraint of this program is the burden that providing support to thirty-one (or more) individual agencies would put on the program. Therefore, it is recommended that the technical support be provided to GMAs rather than individual agencies.

The cost of providing this Technical support may be offset through involvement of technical experts from both public and private agencies. Experts in the fields which are needy of attention within the County may be approached to volunteer a few hours of their time to conduct a workshop or answer questions. Incentive to public agencies would be to improve or reaffirm interagency coordination, while incentives to private firms include an opportunity to introduce themselves to the County's public agencies.

It is recommended that a framework for the development of traffic and incident management strategies be established and that this work be initiated through the IVHS Steering Committee.

The result of this Steering Committee's efforts, or efforts of a committee designated by this group, would be recommendations for the implementation of incident management strategies and draft agreements. These draft agreements could then be fine-tuned to individual agencies' requirements and implemented.

9.4.2 - Decision Support Systems

To implement real-time multi-agency traffic management strategies, it is recommended that some automated support mechanism be provided to develop and propose the strategies such that additional staff is not required at the local levels to handle the multi-agency coordination of various IVHS elements. This mechanism would be in the form of a Knowledge-Based Expert System (KBES), the function of which would be to assess current traffic and incident information, and in response to specific conditions, recommend a combination of actions on both freeway and arterial routes. The Expert System would correlate traffic and incident data, and based on confirmation of incident presence, develop an appropriate response. A related requirement will be for an interface with CHP and Freeway Service Patrol's computer-aided dispatch capability, such that incident reports can be received and updated.

Upon agency approval or modification of these plans, the Expert System would automatically implement these actions on the traffic management system, and update or discontinue these actions as traffic conditions change. Freeway actions may include freeway CMS and HAR messages warning of a downstream incident and advising on alternate routes, and adjustments to ramp metering rates. Concurrent actions on arterial roadways include adjustments in signal timings to handle additional traffic due to the freeway condition, CMS and trailblazer messages which advise on alternate routes around an incident location on the freeway or surface street, and appropriate low-power HAR messages, automatically developed.

This Master Plan focuses specifically on those Expert Systems required for operations on freeways and arterials in Smart Corridor areas. It is proposed that the Expert Systems for each corridor (total of 6) be located at Caltrans and at the appropriate local agencies within each corridor. Maintenance of the knowledge base for the Expert Systems would be determined on a corridor-bycorridor basis, depending on the size and number of agencies involved This would be determined through the consensus of the GM& and Caltrans. These agency-level Expert Systems would transmit the centrally-developed traffic management plan to the local user interface, and would process any modifications the local agency operator would wish to make to the plan, such that the goals of the plan remain intact. The plan would then be automatically implemented at the Caltrans and/or local agency levels, and updated as necessary based on changing traffic flow conditions.

9.4.3 - Emergency Priority System

Emergency signal pre-emption has been shown to be highly beneficial in reducing response times to emergencies such as fires and incidents requiring ambulances. The County's policy is to encourage development of signal pre-emption capabilities across City boundaries. However, the effectiveness of preemption is often perceived as being offset by delays to regular traffic. Current studies have not demonstrated the extent of this impact. However, the incorporation of pre-emption strategies with traffic signal control system operations may provide some degree of mitigation to these impacts.

It is proposed that the capability be developed to provide con&tent pre-emption strategies across agency boundaries where the same fire departments serve both jurisdictions. This is typically true for agencies and unincorporated areas served by the Orange County Fire Department. In addition, adjoining agencies may wish to develop Mutual Aid agreements for their local fire departments to operate across City boundaries when necessary. If Mutual Aid agreements are adopted, it is recommended that a consistent pre-emption strategy be provided across these City boundaries as well.

In order to accomplished the above, a study of the effects and benefits of signal pre-emption on a multi-agency corridor should be conducted. This study should identify corridors in the County where pre-emption across city boundaries is feasible and could be desirable for emergency purposes. The test corridor should first be modeled to estimate the traffic impacts of pre-emption relative to the benefits of providing preemption to emergency vehicles. If the results of this modeling exercise are favorable, emergency signal preemption should be instituted on a test basis for further evaluation of purposes.

It should be noted that preemption devices using alternate technologies to the traditional strobe-light detection (e.g., 3M's Opticom System) are now being introduced (e.g., spread spectrum). It is also foreseen that pm-emption may incorporate technologies such as GPS-based AVL systems in the future. Therefore, it is considered too early in the technological development stages of preemption to recommend that a single county-wide system be developed. Rather a competitive market should determine the preferred technology(ies) and encourage standardization among manufacturers once the preferred technologies are determined.

9.4.4 - Rapid Incident Clearance (RIG)

To encourage the rapid removal of incidents, a number of actions may be taken which can contribute to reducing incident-related congestion. The full county-wide deployment of the Freeway Service Patrol is likely to reduce response times for both stalls and accidents. However, the rapid clearance and removal of incidents from the freeway is absolutely essential, and this must be accomplished with the assistance of more streamlined investigation and vehicle removal procedures.

CHP/FSP Interface with UTIP System. It is recommended that incident reports from CHP and FSP be available for inclusion into the Traveler Information Database. It is also absolutely essential that this information be made available such that a Smart Corridor expert system can confirm any incident reports and then develop an appropriate traffic management plan for multiple agencies to confirm and implement.

Accident Investigation Sites. It is recommended that locations be developed out of view of freeway mainline traffic for the appropriate CHP investigation of accidents. This is essential to reduce the impacts of "spectator slowing," where motorists slow down to view an accident or police investigation, even if it is removed to the shoulder. It also provides an added measure of traffic safety, in that all parties are off the traveled way.

These sites have been recommended in the Caltrans TOS Master Plan, and the IVHS Master Plan recommends that they be implemented in conjunction with the Rapid Incident Clearance program.

9.4.5 - Adaptive Signal Control and Signal Synchronization Program (ADAPT)

This program will build upon the recent signal synchronization programs occurring in the County. These include the cross-jurisdictional OCUTT projects and the Katella Avenue synchronization project The intent of the program is to expand the synchronization of traffic signals beyond the use of a common multi-agency time-base WWV to development of a real-time traffic response or adaptive signal operation capability in conjunction with regional or corridor-based traffic management strategies. This will be made possible through the INTERTIE program as defined in Section 9.2.2.

Adaptive signal control is currently being evaluated in two separate Operational Tests within the County. Based on the outcome of these tests, one of which is evaluating the integration of adaptive signal ramp and meter control, adaptive signal control will be recommended for those roadways for which adaptive signal control would be expected to have benefits. The GMAs and local agencies should thus assess the outcome of the operational tests. In general, adaptive control would be most useful for surface streets which routinely experience substantial volume fluctuations. Adaptive signal control will require an extensive level of instrumentation of the surface streets and may impact the level of instrumentation. Adaptive signed control will also require appropriate signal controller replacements or upgrades.

Three components of the program will include:

Software Developement: Upgrades to existing local signal systems will include software modifications which allow the use of system detectors to provide traffic data useful for either development and the selection of traffic responsive timing plans or for calculation of adaptive signal timings. Based on the technological assessment in Section 6.5, this would correspond to providing 1.5 GC or 3 GC control respectively, for these roadways in which these levels of improvements are required. Through the modular development of system elements, 4 GC, or predictive development of traffic strategies, can be implemented in the future.

Central Hardware Upgrades: Hardware upgrades will be done in order to accommodate the functional requirements necessary for upgrades to 1.5 GC or 2.0 GC. Depending on the flexibility of existing traffic control systems, this would range from minor modifications to existing hardware to development of an external workstation capable of generating the appropriate signal timings through an existing system.

Field Hardware Upgrades: Field hardware would consist of upgrading controllers which do not have full two-way communications capabilities to new conrollers which are capable of upload/download of signal timings. As a specific, such improvements would require replacement of Multisonics 911 controllers with Multisonics 820A's or other controllers which have two-way communications and plan stage capability. Other field hardware upgrades could also include any modifications to communications required to provide full-duplex communication capabilities between central and field devices.

9.4.6 - Corridor-Based Ramp Metering Strategies

The intent of corridor-based ramp metering strategies is to reduce overall corridor congestion by strategic adjustments in metering rates upstream and downstream of a congested area. This provides improved control of the traffic sources, rather than reacting to a merely local congestion condition as would be done through locally responsive metering (that is, metering rate based on volumes and capacity immediately upstream and downstream of the ramp). Within a defined corridor, such as the six designated Smart Corridors, corridor-wide metering strategies need to be developed in conjunction with the necessary traffic response and management strategies developed for freeway and surface street operations.

Implementation of corridor traffic-responsive ramp metering strategies is recommended for the Caltrans TOS, as well as in conjunction with the development of Expert System response strategies for the Smart Corridors.

Corridor metering involves a full consideration of real-time freeway and surface street operational constraints. Strategies are to be agreed upon by both Caltrans and the agency with jurisdictional responsibility for the surface street affected by the ramp metering. These strategies will be arrived at through a manner similar to that of other incident management strategies.

9.4.7 - Integrated Signal/Ramp Meter Control

The integration of traffic signal and ramp metering control will be the extension of corridor metering strategies. Similarly, these strategies will be agreed upon by Caltrans and the local agency. Integrated adaptive traffic signal and ramp metering control is currently being evaluated in a City of Irvine-based Operational Test. Implementation may require appropriate signal controller replacements or upgrades.

9.5 PUBLIC TRANSIT/HIGH-OCCUPANCY VEHICLES (HOW PROGRAMS

The IVHS Master Plan will provide an opportunity to support Transportation Demand Management (TDM) strategies through enhanced data collection, information and dissemination of transit and ride&are information. Exhibit 9.5 presents these programs which are further described below:

9.51 - Public Transit/Smart Bus Program

The facilitation of transit use is recognized as a high priority within Orange County. It is anticipated that the integration of transit and traffic information capabilities and the development of Smart Bus technologies will represent a major cornerstone of the overall IVHS Network. A phased implementation is identified in the 1992 Transit IVHS Study developed for OCTA and the City of Anaheim, and is recommended for adoption as part of this IVHS Master Plan These phases focus on the collection, analysis and dissemination of information, and thus the development of the Public Transit/Smart Bus program is integrally linked with the implementation of the UTIP program.

At this time, the transit operations division of OCTA is undertaking a number of projects/studies in the area of IVHS. The following is a brief description of currently identified programs:

Exhibit 9.5

HOV PROGRAMS

Program	Element	Responsibility				
		OCTA	Caltrans	EMA	Local	Private
Public Transit / Smart Bus Program (SMART–BUS)	Transit Operations Center	X				
	Automated Vehicle Monitoring System (in conjunction with Transit AVL)	X				
	Transit TIS	X				
	Electronic Tiiketing System	X				
Red-Time Intermodal Travel Advisory (RITA)	Integrated Transit TIS and UTIP – Transit TIS/UTIP/TID Integration – Integration with UTIP/BBS	 X X				
Interactive Ride&are Program (INTER-RIDE)	Rideshare Database	X	X			
	Interactive Telephone System	X				
	Integration with UTIP Program	X				

- Proposed OCTA/City of Anaheim Transit IVHS Operational Test. This project involves the exploration of conceptual plans for the integration of transit and traffic information on a real-time basis. Benefits to transit operations and traffic management resulting from this integration of information have been define. The design of the Operational Test in the City of Anaheim incorporates data retrieved from Automatic Vehicle Location devices placed on transit vehicles and traffic data from Anaheim's Traffic Management System. This Operational Test design also specifies a traveler information database.

- The evaluation and acquisition of new fixed-route radio equipment. OCTA is scheduled to replace their communication equipment in early 1994. At this time, an evaluation effort is being conducted of the current fixed-route communication system, maintenance issues and current system suitability for the next five years. Feasibility of Smart Bus applications such as automatic vehicle location (AVL), emergency alarms, maintenance status indicators, schedule monitoring, and adherence checking are also being addressed. It is anticipated that this new equipment will incorporate the ability to display information graphically to transit and traffic operators and its customers.

- Replacement of fixed-route and paratransit scheduling software. A study is currently underway to identify those software packages that are available and that can integrate with bus radio communications to accept AVI/AVL data. New software for ACCESS, OCTA's paratransit service, will incorporate interfacing capabilities with mobile data terminals (MDT).

- Other projects include incorporation of a fuel sensors on board transit vehicles for maintenance purposes, and installation of on-board video surveillance cameras to deter crime and vandalism on fixed routes.

As specified by the Strategic Plan for IVHS in the United States, initial deployment of Public Transit/Smart Bus services and systems should include the following:

- On-board transit vehicles: Automated next and current stop information.

- At transit access points: Changeable messages signs with scheduled arrival times.

- In homes and offices: Static transit schedule information and route displays via TV, cable TV, telephone, and personal computers.

- Electronic billing through smart cards for limited transit costs.

- Automated vehicle location systems for fleet tracking.
- Automated fleet maintenance tracking.

In keeping with the criteria for selection of a proposed Early Deployment project, the principal objectives of the Public Transit/Smart Bus Program is to provide a county-wide resource for transit information. It is the intention within the near term to improve transportation service information offered to transit customers and fleet operators by increasing accuracy, and ease of accessibility and by improving fleet performance. With the deployment of APTS service mentioned above, a county-wide network information source will provide travelers with more opportunities to satisfy their travel needs. In the initial stage of deployment, a coordination effort among the agencies is necessary to determine 'how ATMS and ATIS projects can be supported and integrated through the development of APTS technologies.

Data regarding transit vehicle operations will be collected in order to improve the efficiency of both transit operations and traffic management. In addition to improving efficiency, the dissemination of operations information to the public can increase the perceived efficiency of transit, thus making it more attractive.

The later phases of transit development near- and mid-term) will also include the automation of fleet maintenance tracking and vehicle diagnostics as well as electronic billing and ticketing. Similarly, further developments in transit IVHS will continue work towards building efficiencies in transit operations and easing the process of choosing transit as a mode of travel for the public. The primary components of the program include the following:

9.51.1 - Automated Vehicle Monitoring System (AVMS)

The automatic vehicle monitoring system (AVMS) is intended to serve as a fleet management tool for transit operations and an information source for the traveler information system (TIS) data base. The principal element of the AVMS is the automatic vehicle location (AVL) system. Other elements which may comprise an AVMS include diagnostic sensors for the vehicle's mechanical systems, security alarms, and driver communications. A final element may be an automatic passenger counting (APC) system. APC systems have not been included with many previously implemented AVMSs, but most recent or planned applications include this capability.

To realize the benefits of central fleet monitoring and control, the AVMS must be implemented in coordination with the implementation of a Transit Operations Center Additionally, the TIS data base, and ultimately, travelers and traffic managers, will be dependent upon the AVMS for real-time transit information

Additionally, as rail is an increasingly important mode of transportation in the County, and as rail passengers are dependant upon other modes of transportation for transfers to their final destination (e.g., bus, shuttle), it will also be important to identify the locations of rail vehicles. This will assist in the real-time scheduling of these transfers.

This includes incorporation of AVL probes and use of these probes to monitor the bus's location and progress within the roadway network. The AVMS thus serves functions both as a transit management tool and as a system of traffic information probes.

9.51.2 - Transit Operations Center

The transit operations center is the facility used by transit managers and dispatchers to monitor the system's fleet and communicate with drivers. In the most basic sense, the operations center is comprised of the computer hardware and software necessary to receive, store, process and display various information. The elements required to perform this function include a receiver, a computer data bank, software to disseminate data, and monitors and other display devices. To facilitate two-way communication with drivers, the operations center must also have a transmitter. A potential element of the operations center is expert system. This system goes beyond the dissemination of the data, be analyzing the data and identifying or initiating corrective actions.

OCTA's current transit control center serves only as the communication center for dispatch The center monitors the fleet for driver requests to communicate. Upon request or as necessary, communication with the driver is connected via a radio frequency link. The current operations center has the capability to also monitor a silent alarm, a farebox alarm and diagnostic sensors. With the implementation of and AVMS, the operations center would need to be upgraded to accommodate the additional inputs (for example, location data) and to provide enhanced visual display information

9.51.4 - Electronic Ticketing System (ETS)

An electronic ticketing system (ETS), the second generation of advanced fare collection technology, would allow for non-cash fare transactions using an advanced fare media and in-vehicle reading devices.The ETS may provide benefits to the service provider and the service user. The elements of an ETS include in-vehicle (or in-terminal devices or readers, and advanced fare media, ticket dispensing units in terminals and at selected locations, and a central facility with the hardware and software needed to receive, store and process the data. The exact equipment needs are dependant on the type of advanced fare media used. The most common media is magnetic strip farecards, although the use of smart cards for this purpose is gaining support.

The ETS should be implemented as part of a joint effort involving all transit providers in the county. Within Orange County, the agencies that would potentially be involved include the bus and rail operations of OCTA the City of Anaheim (Anaheim People Mover), Amtrak/Metrolink, and the Orange County Fixed Guideway agency. While each provider may be responsible for the implementation and maintenance of reading devices within its own agency, an agreement would be required regarding the shared responsibility for reading or ticketing devices at transfer terminals and ticketing device at activity centers.

The selection and design of an ETS should take into consideration that ETS may be integrated with other components to provide additional benefits. For example, with a tie-in to a bus AVL system, a distance-based fare scheme may be implemented. The ETS may also serve as a form of a passenger counting device for the AVMS. Advanced fare payment (ticket dispensing) and reservations may be included as a feature of the ATIS.

9.5.2 - Real-Time Intermodal Advisory

Similar to in-vehicle navigation, the development of real-time multi-mode routing will be an extension of the Traveler Information System. In conjunction with the TIS development and integration with transit, algorithms should be developed for use with interactive information systems. These algorithms should provide optimal routing information to the traveler based on analysis of multiple modes of travel and the travelers input (e.g., origin, destination).

9.5.3 - Integrated Real-Time Rideshare (INTER-RIDE)

This program will involve development of a dynamic rideshare database, either accessible via phone or through a bulletin board service integrated with the UTIP bulletin board.

Orange County has made a significant investment high occupancy vehicle (HOV) facilities in terms of both HOV freeway lanes and ramps and public transit. A recommended expansion of OCTA's current ride-matching program includes the development of real-time rideshare capabilities and integration of this system with the traveler information system. By providing rideshare information together with traffic and transit information, through a variety of mediums convenient to the traveler (e.g., interactive kiosks, telephone advisories, PC-based bulletin board systems), use of these HOV facilities can be stimulated. As with all modes of HOV transportation, there is a need to ease the process of trip planning in order to encourage travel through means other than single occupancy vehicles.

9.6 AUTOMATED VEHICLE CONTROL

The basic IVHS infrastructure will be designed to accommodate the future needs associated with automated control and central-tovehicle communications strategies as would be required for automated vehicle control. However, it is expected that most work in this area will occur in the area of in-vehicle, or autonomous, devices designed to enhance driver safety and convenience. These include adaptive cruise control, collision avoidance sensors and warning devices.

In the long term and beyond the time frame of this Study, it is planned that full development of platooning lanes and other automated control facilities will occur within the public sector.

Exhibit 9.6 presents the following expected programs and elements for Automated Vehicle Control services, which are described below:

Exhibit 9.6

AUTOMATED VEHICLE CONTROL PROGRAMS

Program	Element	Responsibility				
		OCTA	Caltrans	EMA	Local	Private
AVCS Operational support	Communications Sewers	X	X			
	AVCS Operations Systems		X			
	In-Vehicle Control Systems					X
Platooning Lanes	Construction		X			
	Electronics / Communication		X			

9.6.1 - AVCS Operational Support

Operational support of AVCS would be expected to include the following elements:

Communication Servers. This would allow communications to vehicles with on-board "may day" devices and AVL, allowing instantaneous identification of incidents and reporting through the central Traveler Information Database (TID).

In-Vehicle Control Systems. These elements include such items as collision avoidance systems, adaptive cruise control, automated braking and vision enhancement devices. In some cases, the in-vehicle systems may require data from the roadway network (i.e., the Traveler Information Database) in order to operate more efficient. An example is adaptive cruise control, which in addition to actual headway from the vehicle in front may also consider downstream speeds and traffic flows and reduce the vehicle speed accordingly. The contribution from the public IVHS infrastructure would purely be in the area of traffic information and vehicle-roadway/roadway-central communications links.

AVCS Operations Systems. In the long term, these systems would be required to control automated platoon lane facilities, including adjustments of speed and ingress/egress of vehicles from the automated facility.

The configuration of such a system is unknown, and will depend on the level of technological advancement and research occurring in the AVCS area.

9.6.2 - Platooning Lanes

The long term development of automated platooning lanes to carry high volumes of vehicles at high speeds with short headways will include extensive electronics infrastructure as well as modification of existing freeway lanes or addition of new lanes along freeway corridors. Additionalresearch and testing is required in order to establish the proper geometric configurations.