Regional Approach to Strategic Intelligent Vehicle Highway System Planning in Orange County

GLENN N. HAVINOVISKI, BARBARA LEONARD, AND DEAN DELGADO

The Orange County, California, Intelligent Vehicle Highway Systems (IVHS) Study has developed a framework under which advanced technologies will be deployed to improve the operation of the county's highway and public transportation system. The most significant challenge of the study was to reconcile an overall high-level transportation vision with the needs, concerns, responsibilities, and financial limitations of all the local and regional agencies. The process used to develop a regional IVHS strategic plan is described and a review of the required areas of emphasis in developing such a plan is discussed.

The Orange County, California, Intelligent Vehicle Highway Systems (IVHS) Study has developed a framework under which advanced technologies will be deployed to improve the operation of the county's highway and public transportation system. Commissioned by the Orange County Transportation Authority (OCTA) and conducted by a team of consultants led by JHK & Associates, the study is a culmination of the following activities:

1. Identification of regional and local transportation goals;
2. Analysis of IVHS strategies and technologies that support these goals;
3. Identification of a transportation network for IVHS improvements;
4. Investigation of institutional issues associated with the implementation of IVHS;
5. Development of an IVHS master plan defining specific programs and an implementation strategy and an action plan that identifies specific projects and priorities, including estimated costs and funding availability; and
6. Preparation of final report that documents the project activities and findings.

These activities are illustrated in terms of the overall study process as shown in the flow diagram in Figure 1.

APPROACHES TO IVHS STRATEGIC PLANNING

The development of a strategic IVHS plan can be approached in various ways, on the basis of the scope of the project. For example, the work on the national level by IVHS America has focused on defining an overall direction for IVHS technologies and an overall approach to utilizing advanced technologies to solve transportation problems. Statewide studies such as those completed in Colorado and Washington State provide an overall vision and a general direction for development of programs. However, a key element in statewide IVHS planning is determination of the appropriate needs of specific regions. By nature, most states have several types of regions, ranging from major urban areas to smaller cities to rural areas. Although it is relatively elementary to identify an overall "high-level" IVHS vision and program for a region, a major issue is how the various local and regional agencies will be able to work together to implement the regionwide system, given their existing infrastructures and their inevitable limitations in the area of funding, staffing, and available expertise.

The most significant challenge of the Orange County IVHS study was to reconcile the overall vision of an integrated, multimodal transportation management and information system to serve the public, with the needs, concerns, responsibilities, and financial limitations of 31 cities plus several regional agencies. Important to the successful implementation and operation of IVHS in Orange County, as anywhere, is the realization that IVHS requires dedicated sources of funding and staff commitment for continued operations and maintenance. This need must be realized and met by public agencies responsible for the management and funding of transportation, politicians whose support is necessary to carry out programs, and the public.

GEOGRAPHIC AND DEMOGRAPHIC DESCRIPTION

Orange County, California, with 2.5 million people, is located between Los Angeles and San Diego along the Pacific Ocean. Historically an agricultural and later a predominantly residential area, the county has seen a considerable amount of growth since the 1950s, including substantial commercial, retail, and residential development. The county also contains a number of major tourist attractions, including Disneyland and Knott's Berry Farm. Other recreational trip generators include Anaheim Stadium and Arrowhead Pond (major league sports and concerts), as well as Irvine Meadows and Pacific Amphitheaters, and seasonally, the Orange County Fair and the beaches along the Pacific.

An extensive network of freeways and surface streets has been developed in the county, and the problem of major congestion during both peak and off-peak periods has been confronted. A countywide bus transit system, operated by OCTA, is being augmented by expanded commuter rail service in the Los Angeles-San Diego and Orange County-Riverside corridors. This expanding

G. N. Havinoviski, JHK & Associates, 300 South Harbor Boulevard, Suite 516, Anaheim, Calif. 92805. B. Leonard, Barbara Leonard Associates, 1125 Rosedale Drive, N.E., Atlanta, Ga. 30306-3914. D. Delgado, Orange County Transportation Authority, 550 South Main Street, P.O. Box 14184, Orange, Calif. 92613–1584.

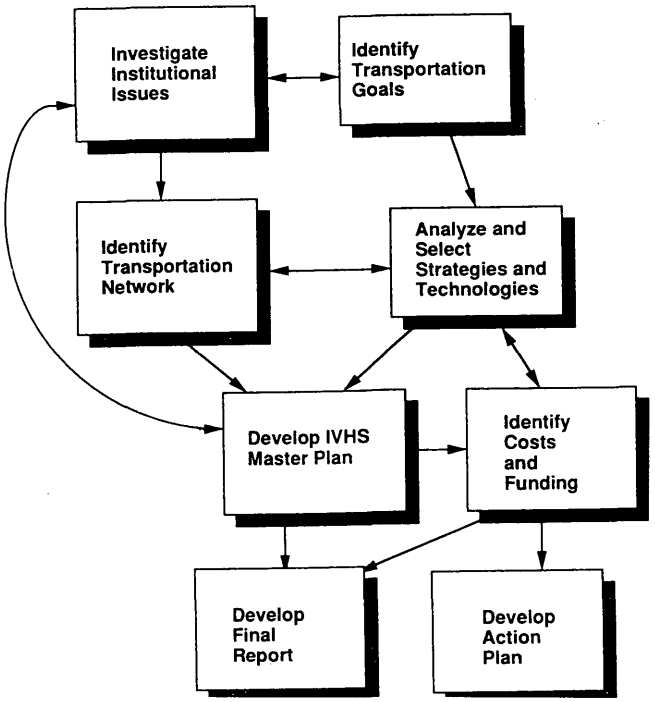

FIGURE 1 Orange County IVHS study process.

public transportation infrastructure, from a regional agency standpoint, is considered to be an increasingly valuable element of the overall transportation network.

IDENTIFICATION OF STRATEGIES AND TECHNIQUES

The first step in the development of the IVHS planning process for Orange County was the identification of local and regional transportation needs. Goals and objectives for the county's regional and local transportation systems were identified through interviews with state, county, and local agencies; neighboring agencies; and private institutions such as major activity centers, transportation management agencies, and the media. Additionally, national IVHS goals were assessed in relation to the county's needs. Eight primary goals emerged, the first five addressing transportation goals, and the remaining three addressing goals of the system architecture:

1. Increase efficiency,
2. Decrease emissions/energy use,
3. Enhance safety,
4. Support transportation operations and planning,
5. Improve quality of life,
6. Minimize cost,
7. Allow evolvability, and
8. Increase robustness.

The consultant team identified strategies that support the county's goals and related objectives (Figure 2). Finally, the strategies, which are independent of technology and type of improvement, were combined into sets of strategies similar in nature to assist in identifying user services, and their associated IVHS technologies and elements, which could be used to solve the various transportation problems in the county. Fifteen global strategies emerged, as presented in Figure 3. These strategies are correlated in this table to the IVHS user service categories, as defined by FHWA. These include traveler information, traffic management, freight and fleet management, public transport and emergency vehicle management, and additional services.

TRANSPORTATION NETWORK

To prioritize field improvements for the benefit of passenger vehicles, public transportation (e.g., buses, paratransit, rideshare), and commercial vehicles, an IVHS transportation network was identified. Those improvements that are more global in nature or are vehicle based, such as traveler information and Smart Bus operations, are detailed within the IVHS master plan, as discussed later in this paper. Orange County is fortunate in that a number of studies of the physical roadway network were conducted previously. The findings from these studies were incorporated in the analysis of the IVHS network, and the following classifications resulted (this list does not necessarily represent order of prioritization):

- Smart corridors: freeway segments with identified recurrent and nonrecurrent congestion and their arterial alternates;
- Smart streets: arterials located at regular intervals that have the ability to serve as freeway corridor replacements or freeway linkages; and
- Locally identified priorities such as
  - –Planned toll roads and
  - –Supplemental freeway segments: those freeway segments not identified as smart corridors.

Where the specific functions and nature of each of these categories of roadways (Figure 4) identified the need, various elements were recommended for implementation. These include "typical" traffic management system elements, including changeable message signs (CMS) and closed circuit television (CCTV) cameras, plus traffic control improvements. These include improved signal synchronization and adaptive control capabilities as well as integrated corridor signal and ramp metering operations. Various advanced surveillance elements, including video image processing, are identified for especially high-traffic or high-incident locations.

In addition to these facilities, public transit vehicles (buses, as well as fixed guideways, such as commuter rail lines) are recommended for deployment of vehicle location, data collection, and en-route information devices.

INSTITUTIONAL ISSUES

To assess the impact of institutional issues and establish a consensus with regard to the direction of IVHS programs in the county, the consultant team received direction and comments from a number of OCTA oversight groups at both a policy level and a technical level. In addition, interviews were held with public agencies and private institutions about transportation within the county. These interviews focused on a number of issues:

1. Signal pre-emption for emergency and transit vehicles,
2. Incident management and freeway construction projects,
3. Special event traffic management,
4. Interagency traffic management,
5. Transit and IVHS, and
6. Air quality and IVHS.

Goal Objective Strategy

1 INCREASE EFFICIENCY

- ***1.1 Manage Demand***
  - 1.1.1 Transportation Demand Management
  - 1.1.2 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
  - 2.2.3 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
  - 2.3.2 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
  - 3.1.2 Decrease Turbulence
  - 3.1.3 Prevent Unsafe Driving
- ***3.2 Reduce Severity of Accidents***
  - 3.2.1 Eliminate Infrastructure Hazards
  - 3.2.2 In–Vehicle Safety Measures
- ***3.3 Avoid Secondary Accidents***
  - 3.3.1 Warn Driver
  - 3.3.2 Respond to Incident
  - 3.3.3 Clear Incident

FIGURE 2 Orange County IVHS architecture: goals, objectives, and strategies (*continued on next page*).

The interviews resulted in the development of an agency consensus, definition of a specific wish list of improvements, and identification of various constraints and concerns about the development of IVHS programs.

Agency Consensus

In general, it was felt the agencies can and do work together. However, it was felt that a greater degree of coordination between local and regional/state agencies was needed. At the same time, although most of the transportation problems in the county are interagency in nature, the communities are in fact diverse. Although several cities boast major commercial and retail development as well as residential areas, many communities are primarily residential and are sensitive to additional traffic flows or resultant congestion within their respective communities. Clearly, the various agencies wish to retain their autonomy and maintain control over their facilities even as part of a coordinated interagency transportation system.

Wish List of Transportation Management Improvements

A number of specific items or programs were desired by the agencies as part of the development of IVHS programs for the county. These programs included many institutionally related elements,

Goal Objective Strategy

3.4 Speed Emergency Response
- 3.4.1 Respond to Incident
- 3.4.2 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
- 3.6.2 Provide Pre–Trip Information to Traveler
- 3.6.3 Provide Information to Motorist in Vehicle
- 3.6.4 Preplan for Incidents
- 3.6.5 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
- 4.1.2 O–D Data based on AVI/AVL/VIPS
- 4.1.3 Credible data analysis 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 Information
- 4.3.2 Interactive/Intuitive Information Display
- 4.3.3 Decision Aids

5 IMPROVE QUALITY OF LIFE

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

FIGURE 2 *(continued).*

such as interjurisdictional cooperation in developing traffic management plans and improving real-time notification of incidents that may affect a specific community or roadway segment. Also important to local agencies was the availability of technical assistance to help operate newer traffic management elements that require a higher level of maintenance than do existing elements.

System improvements that were identified by the agencies included improved signal control and coordination for enhanced flow, improved real-time system monitoring, and the use of mobile CMSs featuring localized seasonal travel information (e.g., beach parking) in lieu of permanent CMSs in most communities. In general, public transit was a much greater concern at the regional level than at the local level, and an emphasis on improving public transit use was considered an important global function of the IVHS programs for the county.

Constraints and Concerns

The agencies identified various constraints and concerns about the implementation of IVHS programs, such as limited staff availability for operations, maintenance, and participation in regional meetings. Another concern involved the availability of measurable benefits relative to the estimated system expense. Finally, many areas exist in the county where the capacity of both primary and alternate routes is insufficient, thus frustrating attempts to reroute traffic.

Goal Objective Strategy

- ***5.3 Equity regardless of socio–economic status, disabilities, etc.***
  - 5.3.1 Intelligence in Infrastructure rather than in vehicle
  - 5.3.2 Multi–lingual, both audible and visual information
  - 5.3.3 Wheelchair accessibility of mass transit
- ***5.4 Equitable distribution of costs and benefits***
- ***5.5 Enhance Economic Vitality***
- ***5.6 Decrease Noise***
  - 5.6.1 Sound Barriers
  - 5.6.2 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
  - 5.7.2 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
  - 7.1.2 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 ROBUSTNESS

- ***8.1 Provide 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
  - 8.2.3 Modularity
- ***8.3 Adapt to Changing Traffic Patterns***
  - 8.3.1 Modularity
  - 8.3.2 Expandability
  - 8.3.3 Relatively Load–Insensitive Design

FIGURE 2 (*continued*).

INTERAGENCY RELATIONSHIPS

Of primary importance to the development of the regional IVHS is (*a*) that jurisdictional responsibilities and autonomy are preserved and (*b*) that the organizational structure is oriented toward efficient planning, implementation, and operations. The proposed structure for Orange County allows for jurisdictional responsibilities to be kept intact and provides the agencies with an opportunity for direct and indirect input to program development and management. These opportunities were identified through the following:

- Development of an IVHS steering committee with representatives from various areas of the county, plus California Department of Transportation (Caltrans), California Highway Patrol, and

Strategy \ User Service	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)

FIGURE 3 Relation of IVHS user services to Orange County transportation strategies.

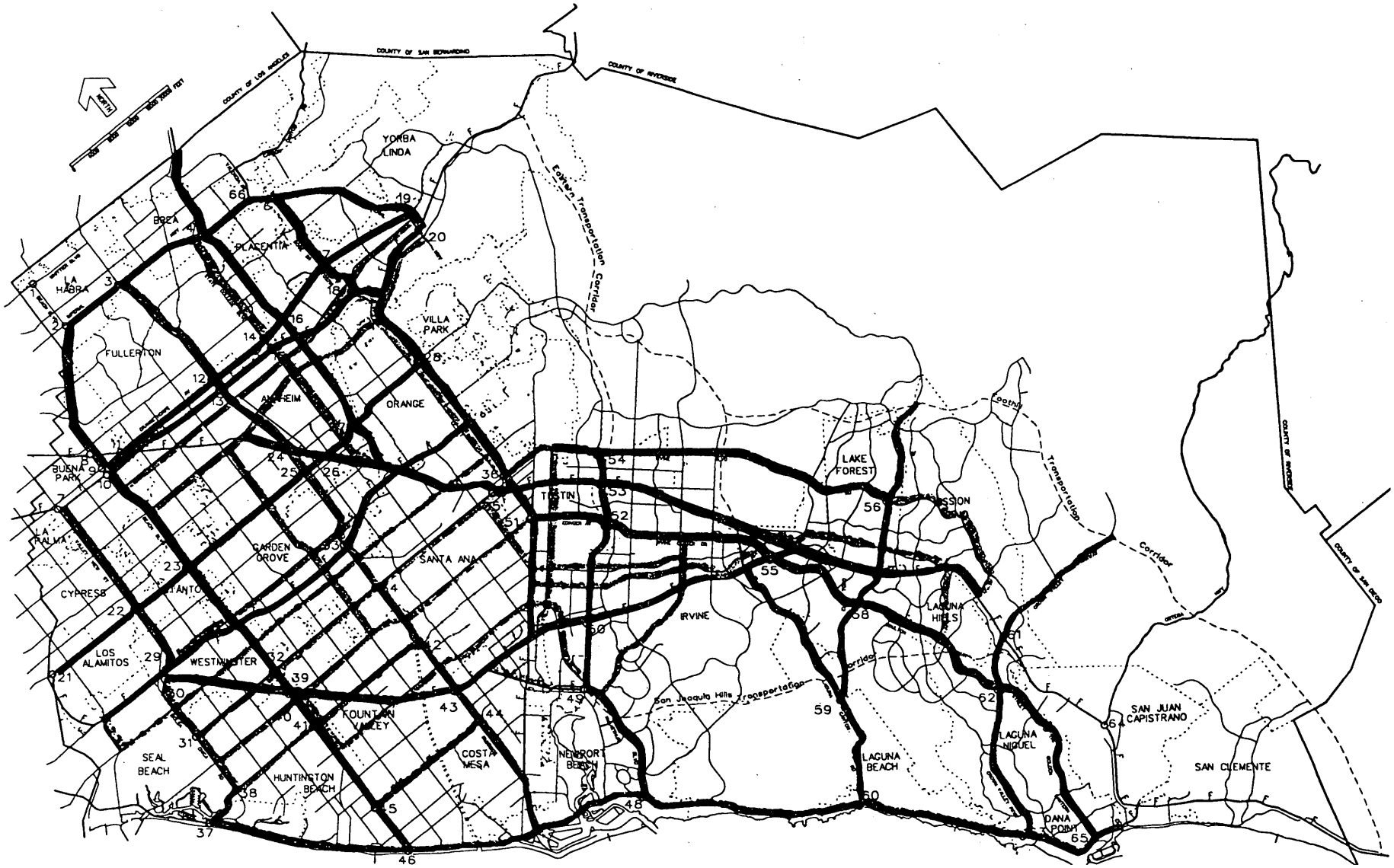

FIGURE 4 Preliminary IVHS network for Orange County.

the Automobile Club of Southern California. The responsibilities of the steering committee would include directing the development of IVHS in the county. These duties include the following:

–Identifying future programs and modifications to master plan,
–Securing funding,
–Implementing programs,
–Providing technical support,
–Developing traffic response/incident management plan, and
–Setting technical standards.

- Employment of an IVHS administrative staff by OCTA, the one agency within the county with responsibility for the entire transportation system, including streets and roads and transit. The administrative staff would carry out any and all of the administrative functions of the steering committee's responsibilities under the direction of the IVHS Steering Committee. Additionally, the administrative staff would be responsible for the following:

–Coordinating with multiagency growth management associations (GMAs),
–Providing support services to the steering committee,
–Maintaining draft agreements,
–Coordinating regional identification and formulating projects,
–Identifying and pursuing funding sources, and
–Coordinating projects.

The GMAs represent the cities as grouped in geographical subdivisions of the county. These areas were developed to implement transportation improvements in conjunction with Measure M, the county's ½-cent sales tax dedicated for transportation. It was recommended that the activities of the GMAs be expanded to incorporate subregional development, planning, implementation, and administration of IVHS programs. Local agencies, if they choose to coordinate through the GMAs, can work cooperatively as a subregion to further IVHS within their area. The latter is particularly important because much of the funding for IVHS on the regional, state, and federal levels places a high emphasis on the regional aspects of transportation improvements.

PROPOSED IVHS ARCHITECTURE

On the basis of an analysis of technologies and institutional implications of a countywide IVHS architecture, three alternative scenarios were considered, as indicated in Figure 5. These included a fully centralized architecture (centrally concentrated control, management, and dissemination), a decentralized architecture (similar to that of existing operations), and a hybrid architecture combining attributes of each of the above. The recommended hybrid architecture specifies the interconnection of local traffic management centers (TMCs) for local monitoring and control, a freeway traffic operations center (TOC), and a countywide multiagency traveler information center (TIC) for fusion of status data for distribution to travelers as well as the agency traffic managers (Figure 6).

The system centers around the collection, evaluation, and dissemination of data. The local TMCs and TOC receive data from whatever detection devices or other resources they use (e.g., loop detectors, CCTV, or police reports). These data are used to monitor the traffic in the jurisdiction and are also passed automatically to the TIC, where they are merged with data from throughout the county to form the countywide status. This status can then be called up by any TMC or by the Caltrans TOC. Furthermore, the TIC will alert any TMC or the TOC of incidents or events to which it should re-

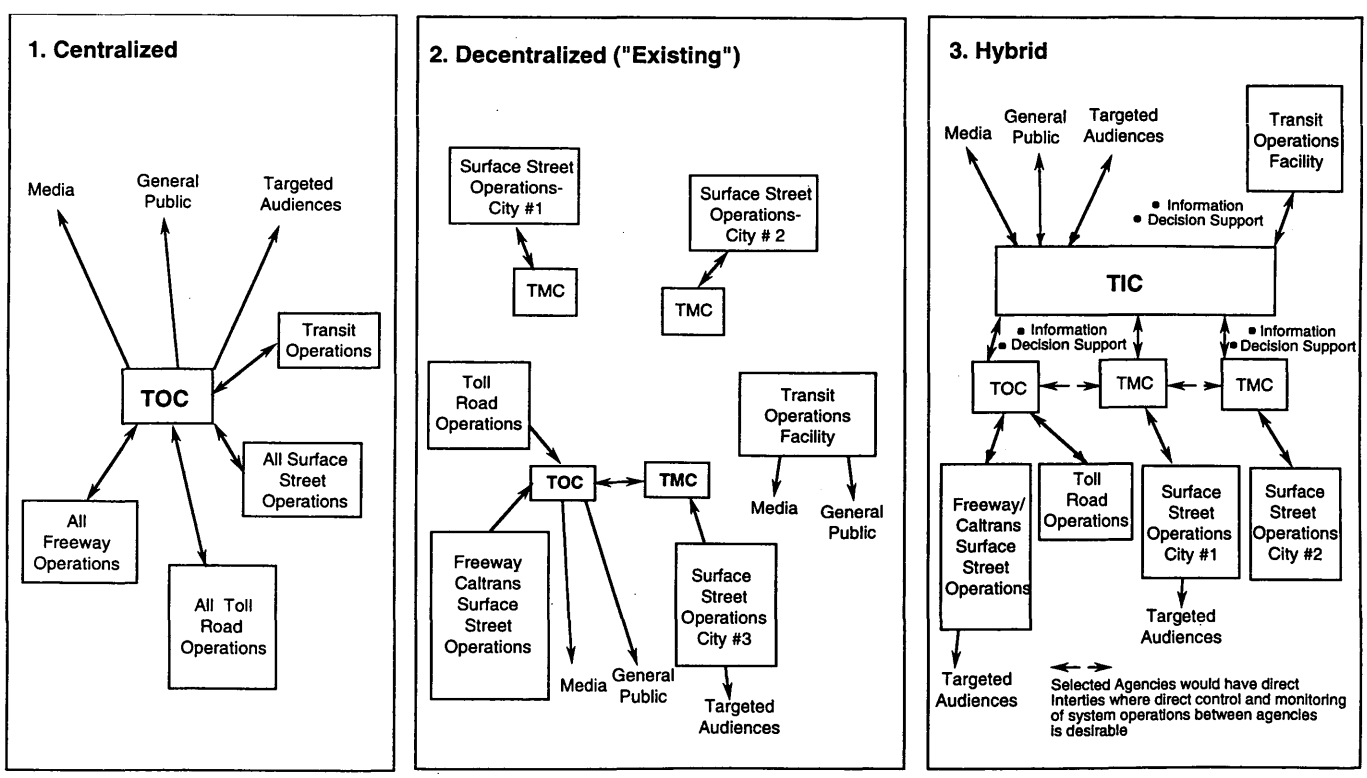

FIGURE 5 Comparison of IVHS organizational structures.

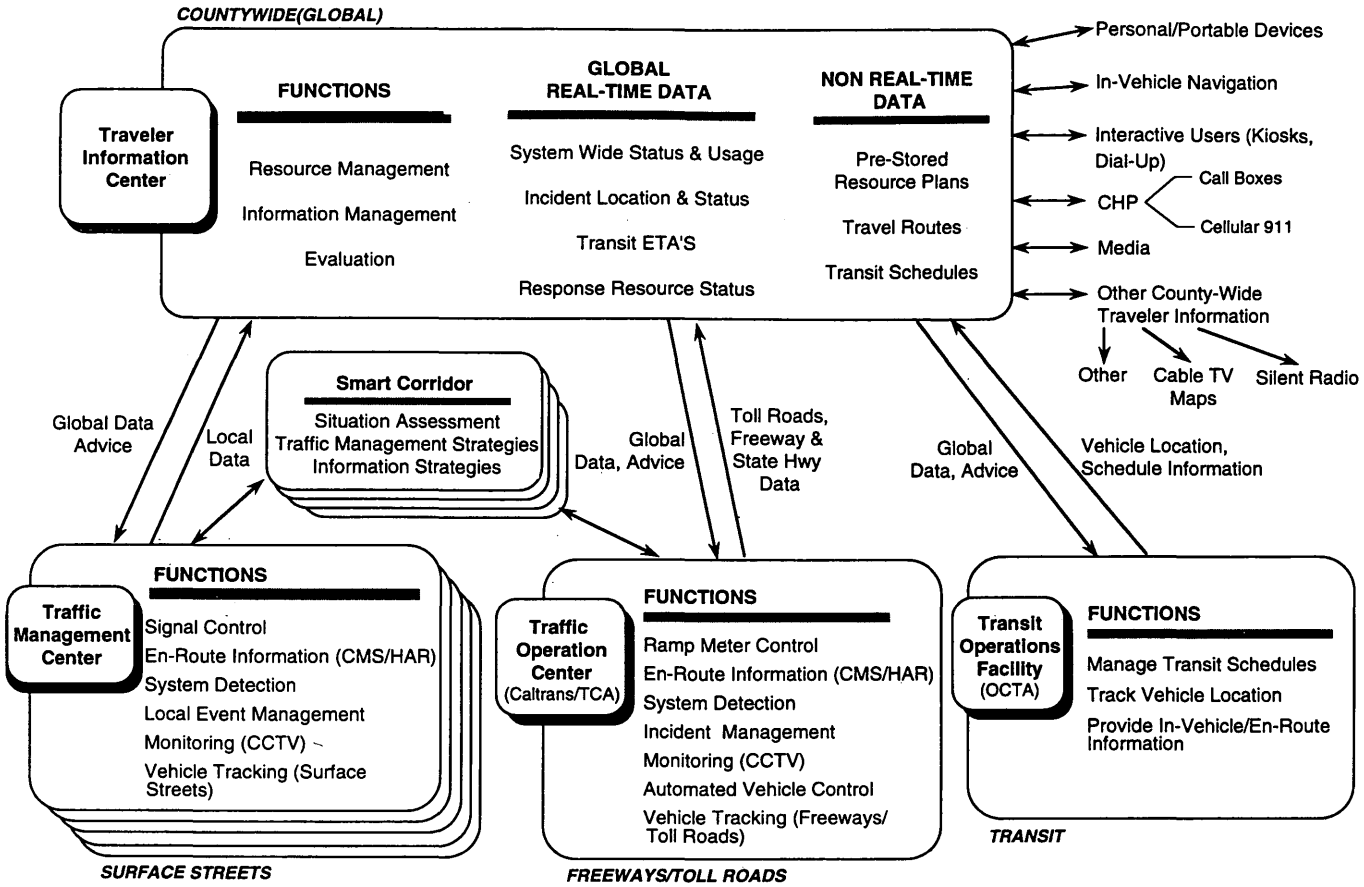

FIGURE 6 Overall structure: Orange County IVHS elements.

spond. Decision support systems (e.g., knowledge-based expert systems) will advise action. For example, a major accident on a freeway will cause one or more TMCs to be notified and asked to approve previously agreed upon multijurisdictional diversion plans.

IMPLEMENTATION STRATEGIES

The program development strategy leading to the IVHS master plan for Orange County was done in an incremental, building-block fashion. Two examples are presented below—one related to program development and the second related to an existing infrastructure. Unlike the "top-down" strategic development process, which is driven by a regional consensus and various high-level policy goals, the "bottom-up" program development process takes into account existing programs and constraints and utilizes these as the basis for development of an IVHS architecture.

Programmatic Example

In Figure 7 a programmatic example is given for the implementation of traveler information programs in the county. The programs were designed to build on existing elements, then incrementally develop elements that are capable of supporting the ultimate system. Two of the most critical near-term elements of the program are the development of a traveler information data base (TID), which serves as a clearinghouse for real-time traffic and transit information, and interagency links (interties), which allow the exchange of information between the agencies and the TID. These serve as building blocks on which the ultimate system is developed.

Systematic Example

The second example (Figure 8) is of the development of an arterial-based advanced traffic management system (ATMS) and is particularly relevant to the interrelationship of local and regional traffic operations. ATMS was a key element in the presentation to local agencies of how existing systems can be incorporated into an IVHS architecture. This example illustrates how the incremental development of an overall IVHS infrastructure can achieve specific objectives. These range from an isolated traffic signal (the most basic traffic management element other than a stop sign or striping) to real-time centralized system operations, to interagency coordination, and finally, to a regionwide system at the top level.

The regionwide system allows multiple agencies to share information and coordinate operations. Such a scheme is typified by the "smart corridor" concept, now being implemented in Los Angeles. Operator and traveler decision support systems (e.g., expert systems, interactive multimode traveler information systems) obtain data from local systems or a TID and provide tools for systemwide

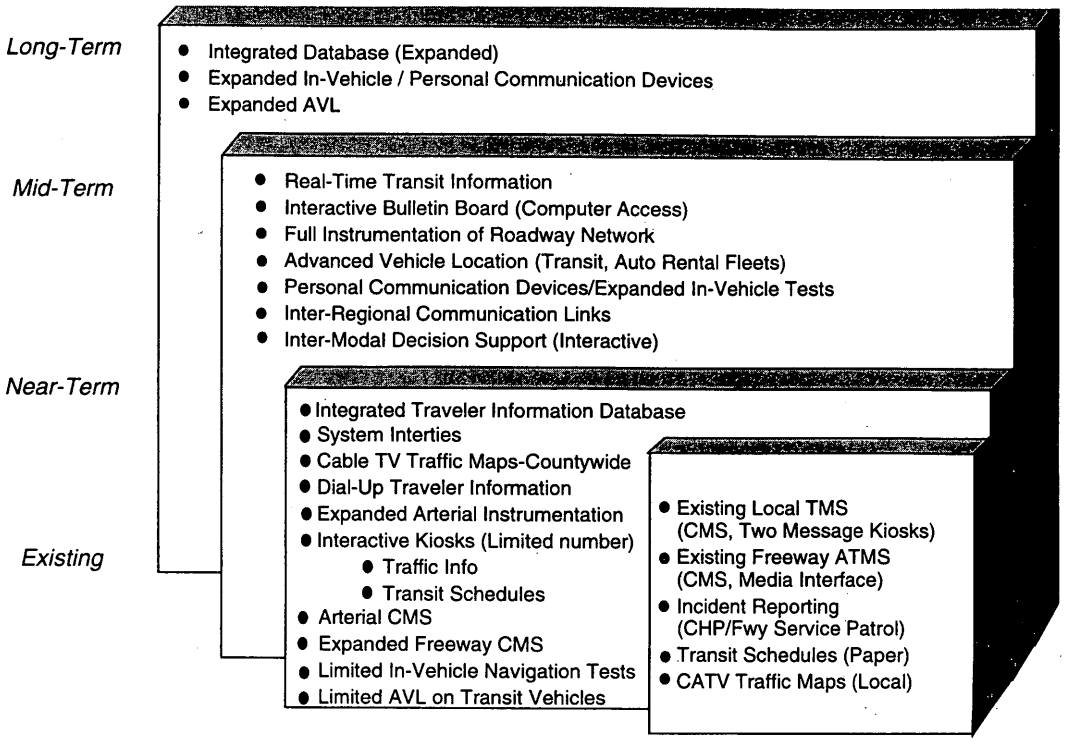

FIGURE 7 Programmatic IVHS development: traveler information programs for Orange County.

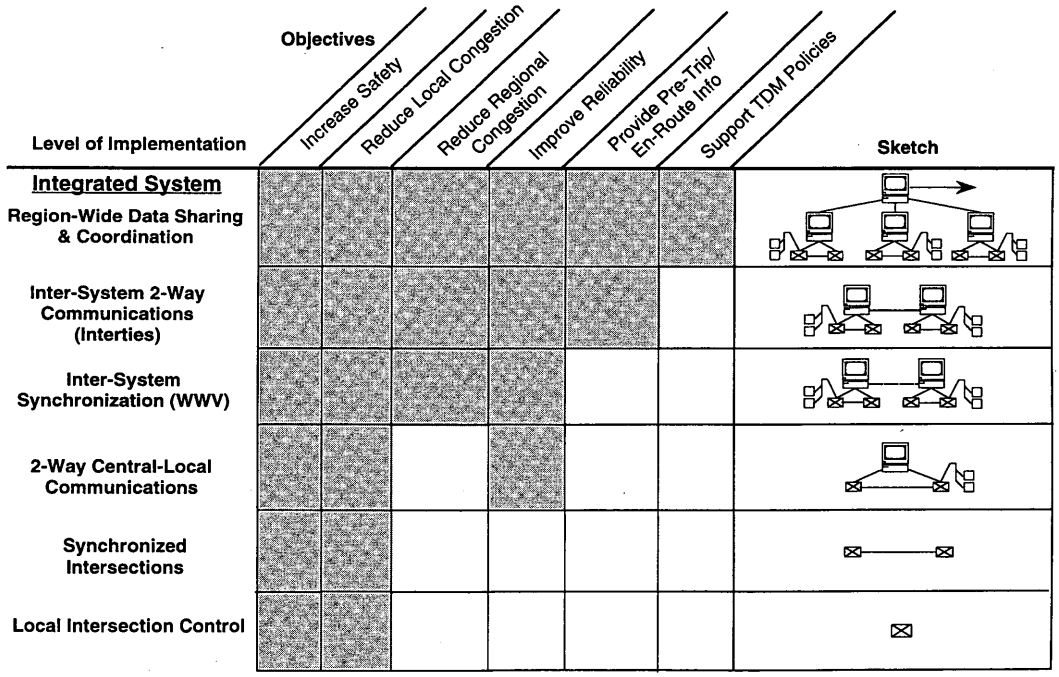

FIGURE 8 Implementation of arterial ATMS elements.

analysis. To support agency operations, coordinated interagency responses can be "downloaded" to the local systems for their confirmation and implementation. To support traveler information, appropriate guidance data (recommended mode, route, etc.) can be developed and displayed to travelers.

Existing Infrastructure

In Orange County a significant amount of effort has been placed into freeway management and signal synchronization. Caltrans is expanding the use of ramp metering, has been expanding CMS locations, and has been adding CCTV and loop detector stations to the existing surveillance system. It is also in the process of expanding its regional freeway TOC in line with a statewide TOC master plan.

Most of the local agencies in the county maintain some form of signal system. These range from Anaheim's centralized urban traffic control system to a number of closed-loop systems (smart field masters with central monitoring and download capability). Three cities have or are in the process of implementing CMS and CCTV elements as well as highway advisory radio.

However, the traffic operations backbone for more than half the agencies in the county consists of proprietary centralized traffic control systems that are vendor specific in terms of hardware and software. The nature of these systems over the years has been that they are incapable of sharing information with other systems. Activities are now under way by both the vendors and the agencies to permit the export of traffic information and signal status data.

The key of the IVHS architecture must then be to ensure that the information from the various agencies is compatible in both form and protocol. To that end, the study recommended the development of a countywide information protocol and linkages between local area networks located at various TMCs or encompassing various agencies. The Ethernet interface standard provides a solid foundation for standardized communications, as does the use of a protocol such as TCP/IP.

A number of current projects already have resulted in interties between Caltrans and local agencies to allow the sharing of local and freeway traffic information. Further improvements are resulting in the sharing of CCTV images between local agencies and Caltrans, such that an integrated approach to traffic monitoring and response can be implemented. In addition, the City of Anaheim has developed a traveler information system that provides interactive traffic information capabilities through dedicated kiosks, as well as a rotating color traffic flow map presented to local cable television subscribers on a community access channel.

IVHS MASTER PLAN

The recommended IVHS programs for Orange County include five of the following categories of development that are similar to the previously identified user services:

1. Traveler information,
2. Monitoring and data collection,
3. Traffic management,
4. Public transit/high-occupancy vehicles, and
5. Automated vehicle control.

The programs are described in Figure 9, along with estimated overall costs, including annual operations and maintenance.

ESTIMATED BENEFITS

The estimation of benefits relative to IVHS improvements is a difficult endeavor because many of the elements are new and are in the process of development or operational testing. Therefore, the analysis relied on the project team's experience from involvement in previous studies or projects that included a number of the traffic management or traveler information elements incorporated into the proposed countywide IVHS architecture. Elements evaluated included freeway incident management tools (incident detection, rapid response techniques using service patrols, and CCTV), traveler information elements (roadway-mounted CMSs, and limited usage of in-vehicle navigation tools), and traffic control (adaptive or traffic-responsive signal timing, corridor ramp metering). Because these are a subset of all the program elements recommended previously, the benefits assessment is thus conservative. At the same time, it was decided to compare this limited assessment of benefits with the total cost of IVHS improvements.

The analysis estimated the following benefits using the year 2005 as a base:

- Annual delay reduction benefit of $243 million (based on 34 million vehicle-hours saved at a $7.20/vehicle-hour delay cost as used by Caltrans) (*1*);
- Annual accident benefit of $48.9 million based on a 25 percent reduction in freeway accidents (12,000 accidents annually in year 2005 were estimated, at a cost of $16,300 on the basis of 1989 Caltrans data) (*2*); and
- Annual fuel consumption reduction benefit of $25.29 million (0.6 gal per vehicle-hr reduction at $1.25 gallon, based on above delay reduction)[2]

The conservative estimate of monetary benefit is $317 million annually, not including the impact of such IVHS-related improvements as real-time transit scheduling and information (and resultant impacts on mode split), as well as vehicle control and safety improvements. Given an estimated annual cost of $80 million for all except automated highway improvements and privately developed in-vehicle systems, this would result in a benefit-cost ratio of 4:1.

SUMMARY AND OBSERVATIONS

The Orange County IVHS Study, a multiagency, regionally oriented effort, has emphasized interagency consensus and the incorporation of an existing system infrastructure as the basis for a higher level of transportation management improvements. The following are the three major areas of emphasis identified by the consultant team;

- Countywide traveler information (pretrip and en-route),
- Integrated corridor traffic management, and
- Real-time management and information for public transit.

PROGRAM AREA / Programs	Functions
TRAVELER INFORMATION ($272 M)	**Provide transportation network information to public, media, transportation agencies**
Freeway Motorist Information Systems (FMIS)	Expanded roadside CMS & HAR on freeways
Arterial Motorist Information Systems (AMIS)	Roadside CMS & HAR on key arterials
In-Vehicle Information Support Infrastructure for On-Street Navigation (INVISION)	Provide information & vehicle-roadway communications infrastructure to support in-vehicle devices
Universal Traveler Information Program (UTIP)	Develop Traveler Information Center, databases and servers, interactive kiosks
Interagency Transportation Information Exchange (INTERTIE)	Develop distributed interagency communications and processing capabilities (standard interfaces)
Public Information Campaign	Provide public with information on the means to avoid delays through improved driving, travel habits
MONITORING AND DATA COLLECTION ($117 M)	**Provide real-time data for transportation and trip management as well as planning analysis**
Automatic Vehicle Location (AVL)	Equip vehicles with probes to obtain real-time location & operations data for use in travel monitoring & operations
Freeway Instrumentation	Detection, monitoring & surveillance for congestion measurement and incident detection on freeways (CCTV, VIP, detectors)
Arterial Instrumentation	Detection, monitoring & surveillance for congestion measurement and incident detection on surface streets (CCTV, VIP, detectors)
Detector Maintenance	Contracted technical support of local agencies for detector maintenance
TRAFFIC MANAGEMENT ($112 M)	**Enhance agency traffic operations capabilities and support both local and regional operations**
Traffic Management Centers	Build/Expand TMCs for management of state/local roads
Agency Traffic Operations Support (ATOS)	Maintenance Support for Local Agencies' IVHS Elements
Decision Support Systems	Expert Systems for real-time corridor traffic management
Emergency Priority System (EPS)	Testbed for interagency coordination of signal pre-emption through integration with TMSs for reduction of delays
Rapid Incident Clearance (RIC)	Expand Freeway Service Patrols and integrate reporting capabilities with UTIP program
Adaptive Signal Control and Signal Synchronization Program (ADAPT)	Enhance real-time traffic signal control (central and field improvements, software modifications)
Corridor Ramp Metering	Enhance real-time freeway flow through coordinated corridor metering strategies
Integrated Signal/Ramp Meter Control	Improve local signal/meter coordination to reduce impact of restrictive metering rates on surface street traffic
PUBLIC TRANSIT/HIGH-OCCUPANCY VEHICLES ($12 M, in combination with other programs)	**Support Transportation Demand Management policies through collection and dissemination of real-time transit/HOV information**
Public Transit/Smart Bus	Provide enhanced real-time transit information to public and for fleet management
Integrated Real-Time Rideshare (INTER-RIDE)	Interactive rideshare-matching through phone call-in, interactive UTIP terminals using rideshare database
Real-Time Intermodal Advisory (RITA)	Integration of transit and traffic information, development of real-time comparisons for travel times between modes
AUTOMATED VEHICLE CONTROL ($207 M public sector)	**Support future needs of automated control and central-to-vehicle real-time communications**
AVCS Operational Support	Support AVCS through communications servers and operations systems in conjunction with private sector investment for in-vehicle elements
Platooning Lanes	Provide infrastructure and civil engineering modifications (including new lanes) to accommodate automated control

SYSTEM TOTAL	**Estimated $601 Million**
OPERATIONS & MAINTENANCE	**$80 million annual**

FIGURE 9 Description of Orange County IVHS programs.

To satisfy these areas of emphasis, the study has focused in detail on developing an infrastructure (physical system as well as management) capable of integrating various information and management elements (both roadway and transit) and supporting the extensive interjurisdictional coordination required. Additional effort will be required to provide all of the agencies with the means (technical as well as financial) to support the operation and maintenance of IVHS elements. A key will be the continuous effort in identifying sources of funding that can be used for maintenance of the system.

Although the program emphasis is oriented more to the near term, the architecture developed in the study is highly appro-

priate for support of efforts toward in-vehicle navigation devices and automated vehicle control, efforts that are integral to the overall direction of the IVHS program. Nevertheless, to make the more advanced elements workable, it is necessary to develop a suitable backbone of real-time information and control capabilities. Thus, the nature of this regional IVHS strategic plan has been to emphasize the practicality of implementation as a key criterion.

REFERENCES

1. JHK & Associates. *Bay Area Traffic Operations System Operational Procedures and Strategies Report.* California Department of Transportation, District 4, May 1992.
2. JHK & Associates. *Orange County TOC Study Final Report.* Orange County Transportation Commission, Oct. 1991.

Publication of this paper sponsored by Committee on Intelligent Vehicle Highway Systems.