California System Architecture For Intelligent Transportation: Models For Transportation Systems Management

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CALIFORNIA SYSTEM ARCHITECTURE FOR INTELLIGENT TRANSPORTATION

MODELS FOR TRANSPORTATION SYSTEMS MANAGEMENT

November 10, 1998

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ABSTRACT

In 1996, the Federal Highway Administration completed a program to develop a national system architecture (NSA) for intelligent-transportation-systems. This report presents recommendations on methodologies by which system architecture can be used to improve the deployment of transportation management projects, with emphasis on multi-jurisdictional projects. The report is part of a larger project addressing the deployment of an ITS system architecture in California. The project as a whole is led by Claremont Graduate School, and is documented in a separate report.

EXECUTIVE SUMMARY

The National System Architecture (NSA) program was one of the most prominent and ambitious elements of the Federal Highway Administration's Intelligent-Vehicle-Highway-System program (IVHS, later renamed intelligent-transportation-systems or ITS). As defined by FHWA, a system architecture "is the framework that describes how system components interact and work together to achieve total system goals and objectives." FHWA's goal was to "ensure that the deployment of IVHS user services occurs within the most sensible system framework. It will also ensure that a nationally compatible system emerges, instead of local or regional pockets of IVHS that will not accommodate intercity travel or cross-country goods movements." (FHWA, 1994).

In its Conceptual Approach for implementing the NSA, the US DOT recommends inclusion of the following elements:

- General concept of operations
- Roles and responsibilities for stakeholders
- Linkages with capital improvement projects
- Phasing considerations, both geographic and functional
- Regional technology agreements

This report presents recommendations toward establishing roles and responsibilities and a general concept of operations in California. Specifically, we recommend adoption of a three step procedure for implementing multi-jurisdictional projects:

1. Development of model agreements and policies

2. Negotiating a specific agreement covering participating parties

3. Execution of that agreement in practice

<u>Model Agreements</u>

A model agreement provides “boiler plate” language that could be adopted within any multi-jurisdictional project of a given type, or any universal policy that governs all activities of a given type. They can be developed in much the same way as a standard. An ad hoc committee is formed under the auspices of a recognized organization, such as Institute of Transportation Engineers or perhaps Caltrans, with a single objective of developing a specific type of model agreement. A negotiation and working group process is set to develop the agreement within a set schedule, after which the agreement is submitted to balloting by involved parties. The agreement is accepted if it passes with a super-majority (e.g., 2/3).

Negotiation of Specific Agreements

The model agreement has no force until it is adopted by a multi-jurisdictional project. Organizations entering into an agreement use the model agreement as a starting point, keeping the portions that are relevant and striking others. Specific terms are added to localize the agreement. Once the agreement is finalized at the staff level, it is submitted to higher levels of the organization for formal approval.

Execution

The negotiated agreement provides the structure for how the system is operated on a day-to-day basis. The agreement is only meaningful if all involved parties adhere to its terms, and use it to improve their coordination.

Areas Where Model Agreements Are Needed

The following three examples illustrate where model agreements would be beneficial:

Incident Management Fire districts have a long history of providing aid across jurisdictional boundaries. They have established a simple and effective command and control structure that enables different agencies to work together toward a common objective. A fire department never loses command over incidents within its own jurisdiction (except temporarily, if units have not yet arrived), and a fire department never loses command over its own personnel. A similar command structure was eventually adopted by Caltrans and LA DOT within the Smart Corridor, and should serve as the model for future cross-jurisdictional projects in transportation. The agreement can further specify geographical areas of coverage, the types of incidents that would initiate a cross-jurisdictional response and the magnitude of the response (as has also been done in fire departments).

Flow Management During Incidents The electrical power industry has a simple policy for responding to network incidents, that of sharing remaining capacity in proportion to base level capacity. Networks respond automatically by diverting the traffic of electricity. A simple guideline of this type would be highly beneficial in “Smart Corridor” type projects, where several roadways provide capacity in parallel.

Real-time Network Interfaces In the future, transportation networks will become more like electrical networks, in which the system is continuously monitored and controlled from management centers. However, even the electrical power industry does not attempt to centralize management across jurisdictions. Instead, each agency manages its own network, within prescribed guidelines that prevent failures at network interfaces. The system is controlled through a combination of interface monitoring stations, real-time pricing, and safeguards that ensure that problems in one jurisdiction do not spill over into another. A similar model could and should be developed in transportation. Such an approach could begin with bilateral agreements, but may best be implemented through broader networks that ensure the stability and reliability of the network as a whole. By this approach, the transportation grid can be monitored automatically, with human intervention limited to control measures implemented by individual management centers in response to problems that are detected at interfaces.

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1. BACKGROUND

The National System Architecture (NSA) program was one of the most prominent and ambitious elements of the Federal Highway Administration's Intelligent-Vehicle-Highway-System program (IVHS, later renamed intelligent-transportation-systems or ITS). As defined by FHWA, a system architecture "is the framework that describes how system components interact and work together to achieve total system goals and objectives." FHWA's goal was to "ensure that the deployment of IVHS user services occurs within the most sensible system framework. It will also ensure that a nationally compatible system emerges, instead of local or regional pockets of IVHS that will not accommodate intercity travel or cross-country goods movements." (FHWA, 1994)

The NSA program was completed in two phases. In Phase I, Hughes Aircraft, Rockwell, IBM (later Loral) and Westinghouse were selected to lead parallel design teams (each of these teams included numerous sub-contractors). Each team was encouraged to develop its own unique architectural concept and vision, as summarized below (from FHWA, 1994):

Hughes: "a balancing of intelligence and cost between the vehicle and infrastructure. A range of price/performance products and services provides route selection and guidance to the traveler, and traffic congestion an incident detection data to the traffic management center."

IBM (Loral): "The physical IVHS system will consist of advanced, centralized, regional Traffic Management Centers (TMCs) linked to each other by high speed wide area networks (WANs). Operationally, the regional TMCs will provide human and automated traffic management services, as well as seamless user services, both within a region and across multiple regions as necessary."

Rockwell: "an accommodative, open framework to support user service functionality while meeting the requirements of the service developers/implementers, operators/maintainers, and users. User service functionality is distributed across modular subsystems."

Westinghouse: "increase the people and traffic throughputs to solve the near and mid-term transportation problems while laying out the necessary foundation for advanced technology applications in the far term"

At the end of Phase I, the four teams competed for the opportunity to continue into detailed design in Phase II. The teams were judged both on their architecture and on their performance as a contractor. Hence, the best ideas and talents would be selected to complete the architecture. Rockwell and Loral (formerly IBM) were picked and charged to work together in Phase II, capturing the best features of all four teams in producing the final NSA. NASA's Jet Propulsion Laboratory and MITRE Corporation provided technical input throughout the project. The project was completed in early 1996.

At the present, the US Department of Transportation is working to implement the National System Architecture. This is being accomplished with a standardization program, and through requirements that local agencies are consistent with the National System Architecture in their plans. Consistency is in the process of being defined, but the following "conceptual approach" has been proposed by the US DOT (US DOT, 1998):

"Simply stated, the conceptual approach for ensuring architecture consistency is to require the development of an ITS element of the transportation plan. The ITS element would contain a regional architecture developed using portions of the National ITS Architecture that are applicable in meeting local needs."

The document goes on to propose that the ITS element may include:

- General concept of operations
- Roles and responsibilities for stakeholders
- Linkages with capital improvement projects
- Phasing considerations, both geographic and functional
- Regional technology agreements

This paper presents recommendations on methodologies by which system architecture can be used to improve the deployment of transportation management projects, with emphasis on a general concept of operations and roles and responsibilities (also, see Hall et al, 1998, for concept of operations).

The remainder of the document is divided into three sections. Section 2 reviews the National System Architecture, and describes how it can be used to accomplish system management and control objectives. Section 3 examines multi-jurisdictional projects, and models for improving coordination across jurisdictions. Section 4 examines standard setting, and lessons learned on how standards can be used to enhance technology deployment.

This paper is one component of a larger project directed at creating a California System Architecture. The project as a whole is documented in a separate report.

2. MANAGEMENT AND CONTROL OBJECTIVES

The NSA provides a framework for executing transportation management and control through the use of sensing, communication and information technologies. The framework is defined in two NSA documents:

- *Implementation Strategy* (U.S. DOT, 1996a)
- *Physical Architecture* (U.S. DOT, 1996b)

Transportation management and control comprise processes aimed at achieving smooth and efficient traffic flow, minimal delay and safe travel. Examples include:

- Synchronization of arterial traffic signals
- Ramp metering to smooth highway traffic flow
- Dissemination of information to travelers to balance network traffic flows

- Clearance of traffic incidents
- Bus headway control to minimize passenger delay
- Continuous improvement strategies aimed at removing system bottlenecks

Each of these processes relies on the collection, communication and synthesis of information, and the subsequent formulation of protocols and strategies for acting on the information. Transportation management and control (M&C) also frequently entails coordinated action, spanning jurisdictions, modal and functional agencies, and internal organizational divisions. For example, incident clearance can require coordinated response from highway patrol, ambulance, fire, highway maintenance, HAZMAT and traffic operations.

At present, cross-organizational coordination presents the biggest challenge to M&C, both at a technical and organizational level. At a technical level, it may be necessary to overcome differences in hardware, software, data file structures, and communication protocols. At an organizational level, it may be necessary to overcome differences in objectives, management philosophies and capabilities. Because all of these dimensions can vary enormously from organization to organization, each coordination effort traditionally requires individualized attention and protracted negotiation. Each issue must be resolved on a case-by-case basis, creating long delays and greatly increasing the cost of achieving coordination. A key objective in creating an ITS architecture could be to develop a quick and efficient mechanism that would enable jurisdictions to coordinate transportation management and control and improve system performance. The architecture would contain defined interfaces and decision-making protocols that would remove or greatly reduce the need for negotiation. Once a group of jurisdictions opt for coordinated M&C, the architecture should make implementation a routine process.

The NSA provides a step in this direction, but leaves much to be decided at the state or regional level. The following sections summarize the contents of the NSA with respect to M&C. The focus is on the *Transportation Layer* of the architecture. The Communication Layer provides the means to communicate information in support of the execution of M&C actions. The Institutional Layer defines the feasibility, practicality and acceptability of implementing M&C policies and strategies. The Transportation Layer is where M&C is executed.

The next three sections cover principal elements of coordination:

- Functional areas of responsibility
- Content of communication and information residence
- Lines of authority and resolution of decisions

These topics are followed by a discussion of issues for the State of California and findings from interviews conducted with traffic managers and technology developers. The paper concludes with recommendations for future study.

2.1 Functional Areas of Responsibility

The NSA identifies four key entities: subsystems, equipment packages, market packages and terminators. This section describes these four entities within the context of M&C.

The transportation layer of the NSA contains 19 subsystems, which are grouped into four categories: vehicles, roadside, centers and remote access. The categories are described as follows:

"The *center subsystems* provide management, administration, and support functions for the transportation system."

"[*Roadside subsystems* are] distributed infrastructure subsystems [that] provide the direct interface to vehicles traveling on the roadway network."

"[*Vehicle subsystems*] are all vehicle-based and share many general driver information, vehicle navigation, and advanced safety system functions."

"The *remote access subsystems* include the equipment that is used by the traveler to gather information and access other personal information services prior to a trip and while en-route."

M&C functions are largely executed through just three of the center subsystems:

- Traffic Management
- Emergency Management
- Transit Management

Nevertheless, some M&C functions may be distributed among roadside subsystems, and some M&C functions may be executed within other center subsystems (e.g., toll administration and information service provider). However, these other subsystems are more likely to play support than leadership roles in M&C.

The *Physical Architecture* further defines subsystems in terms of equipment packages and supporting processes. For example, the traffic management subsystem comprises 17 equipment packages, such as "Collect Traffic Surveillance", "TMC Advanced Signal Control", "TMC Based Freeway Control" and "TMC Based Signal Control." The *Physical Architecture* provides one or more processes to be performed by each equipment package.

Cutting across subsystems and equipment packages, the NSA defines a set of 52 *market packages* as the means for implementing ITS. Each market package specifies a cohesive set of services, which are deployed through the architectural subsystems and their equipment packages. The market packages are divided into seven groups:

ATMS: Advanced Traffic Management Systems
APTS: Advanced Public Transportation Systems
ATIS: Advanced Transportation Information Systems
AVSS: Advanced Vehicle Safety Systems
CVO: Commercial Vehicle Operations
EM: Emergency Management
ITS: ITS Planning

Though the market packages are intended to span subsystems, most have a natural "home" in a single subsystem (e.g., APTS packages naturally belongs in transit management and ATMS naturally belongs in traffic management or toll administration). Market packages that are especially relevant to M&C include "Surface Street Control", " "Freeway Control" and "HOV and Reversible Lane Management". These market packages are supported by surveillance oriented packages (e.g., network surveillance) and data processing oriented packages (e.g., traffic network performance evaluation).

The *Implementation Strategy* shows how each market package is supported by the NSA, and how each market package interfaces with other packages. The diagrams show which functions are performed within each subsystem and equipment package and describe (qualitatively) typical data flows between subsystems. The NSA does *not* provide specific communication protocols, file formats, or hardware specifications. The NSA also does not define functionality beyond a general level.

In addition to defining architectural subsystems, equipment packages and market packages, the NSA *Physical Architecture* defines entities "outside the architecture and how the architecture interfaces to them." These outside entities, called *terminators*, are divided into four categories

Human Entities: Employees (inspector, operator, manager, etc.) or Travelers (driver, pedestrian, etc.)

Other Systems Outside ITS: CVO Information Requester, DMV, 911, Media, etc.

Environment (Physical World): Multimodal Crossings, Potential Obstacles, Roadway, Vehicles

Peer Systems Within the Architecture (subsystems): Commercial Vehicle Administrator, Emergency Management Center, Traffic Management Center, etc.

The last category is intended more to represent the deployment of a particular system than for the architecture as a whole. That is, the NSA provides for the deployment of various subsystems, each of which may be required to interface with other architectural subsystems. Each subsystem may then view other subsystems as terminators.

From the perspective of M&C, the division of subsystems into those inside and those outside the architecture is most significant. Outside subsystems include: "CVO Information Requester", "Department of Motor Vehicles", "911 Infrastructure Enforcement Agency" and "Weather Service". Generally, the "other systems" are private entities or public entities whose primary function is not in transportation. Department of Motor Vehicles is an exception. Regional implementation of the NSA may opt to include this as a subsystem.

2.2 Content of Communication and Information Residence

The NSA provides considerable detail on data flows between subsystems. The *Physical Architecture* includes an architectural flow diagram for each subsystem, supported by descriptions of data flows between each pair of subsystems. For example the emergency management/traffic management interface includes four "logical architectural reference flows": emergency vehicle greenwave request, incident information, and incident response status. The general content of each of these data flows is described (but not specified to the point of file or packet format). Each of the specified data flows should be viewed as an optional capability. Any implementation could use all or none of the data flows and, for each data flow, the implementer can customize the content and format of messages. However, the *Implementation Strategy* does associate data flows with implementation of particular Market Packages.

The NSA provides little direction on where information should reside. Based on data flows, inferences might be drawn as to where information originates within the NSA. The *Implementation Strategy* states: "The information sharing [in the NSA] enables a variety of data replication and distribution strategies...For example, neighboring jurisdictions may want to form a centralized database which status's incidents at a regional level, but allow[s] only isolated control for dispatch at each jurisdiction."

2.3 Lines of Authority and Resolution of Decisions

The NSA does not specify lines of authority and resolution of decisions. As stated in the *Implementation Strategy*: "The National Architecture supports various approaches for coordinating traffic management systems in a given region. The control requests support a range of distributed control strategies from strict hierarchies to more general network control configurations." Diagrams are provides to show that the architecture can support hierarchical control, distributed control or completely isolated sub-systems. The NSA expects that individual jurisdictions will establish their own protocols and procedures for responding to communicated messages and for resolving decisions.

2.4 Regional Architectures

The NSA Implementation Strategy states that:

> The National Architecture provides a general framework that may be adapted and elaborated into a broad range of regional transportation system designs. A regional architecture is a key product of this process that begins to overlay major technology and interface choices which are appropriate for the region onto the more general National Architecture definition. A regional architecture ... is a concise formal statement of the architecture choices made by the region. It documents the selected interface standards, regional configuration, and consensus technology choice that will support competitive procurement of systems within the region.

As stated above, the NSA leaves many (perhaps most) of the critical architectural decisions to regional implementers. Nevertheless, the NSA provides a vocabulary that can provide greater compatibility across regions, and focus regional deployment efforts. Fundamentally, however, the NSA defines a set of questions to be answered at the regional or perhaps local level.

From the standpoint of M&C, fundamental questions to address in the effort include:

Geographic Scope: Whether to create a single statewide architecture, multiple architectures divided by region, or participate in a multi-state partnership.

Functional Scope: Whether the architecture should encompass all of the subsystems identified in the NSA; Coverage of market packages and inclusion of equipment packages; Whether additional subsystem should be added and if so which. Which specific agencies will participate in the regional architecture.

Goals and Objectives: Specific aims to be accomplished through the creation of a regional architectures in terms of improvement management and control of the transportation system.

At a more detailed level, the architecture should create specificity in the three areas of coordination: (1) Functional areas of responsibility, (2) Content of communication and information residence, and, (3) Lines of authority and resolution of decisions.

Functional Areas of Responsibility: The NSA defines functions for sub-systems, equipment packages and market packages and defines terminator systems. A regional architecture should associate these generic entities with specific organizations to define spheres of responsibility. A regional architecture should select a set of market packages to support and assign responsibilities for each market package.

Content of Communication and Information Residence: The NSA defines data flows, but does not specify message formats and exact message content. The regional architecture could provide this specificity, and identify how and when messages invoke actions on the recipient. The regional architecture could also define the information to reside in each subsystem and how that information should be accessed by other subsystems.

Lines of Authority and Resolution of Decisions: The NSA is largely silent on authority and decision-making. The regional architecture could define processes and protocols to invoke M&C actions, within such market packages as Emergency Response or Regional Traffic Control. The degree to which decision-making is hierarchical versus distributed, and the role of humans in decision-making could also be resolved.

Numerous opportunities exist to enhance the coordination of M&C functions through the creation of a regional architecture. Tables 1-4 outline four such areas: (1) traffic operations, (2) incident management, (3) flow/capacity, and (4) transit. These are defined on a functional, rather than a system basis, recognizing four principal ways that organizations can be coordinated to improve the management and control of the transportation system. Each table identifies functional objectives, relevant NSA market packages, and coordination opportunities. Coordination can occur within an organization, between peer organizations (e.g., between two separate transit agencies), and across functions (e.g., between transit and traffic).

Table 1. Traffic Operation Coordination	
Objectives	Synchronization, avoidance of cyclic delays (offsets) Match capacity to demand (cycle, phase lengths) Smooth highway flow, increased capacity (metering rate) Diversion (metering rate)
NSA Market Packages	Regional Traffic Control Surface Street Control Freeway Control Regional Traffic Control
Internal Coordination	Synchronization among intersections Coordinated ramp metering
Peer Coordination	Signal Plans for Adjacent Jurisdictions Synchronization of Ramp Meters with Adjacent Signals
Cross-function Coordination	Signal interruption for emergency vehicles Changes in signal plan due to diversion, lane reversals Signal interruption for transit vehicles Signal interruption for train crossings Signal plans for special events

Table 2. Incident Management Coordination	
Objectives	Safety and treatment for involved persons Safety for other drivers, passengers, pedestrians, etc. Safety of EM personnel Rapid detection, response, clearance Minimal delay (capacity loss) during incident Minimal damage to involved/other vehicles Effective load balancing
NSA Market Packages	Incident Management System HAZMAT Management Emergency Response Emergency Routing
Internal Coordination	Dispatching emergency response units to scene
Peer Coordination	Requesting support units (e.g., HAZMAT) Coordinating incident clearance with treatment of injured
Cross-function Coordination	Routing emergency vehicles; selecting clearance alternative Directing traffic to alternate routes Clearance strategy based on truck manifest

Table 3. Flow/Capacity Coordination

Objectives	System optimal assignment of traffic among network links
NSA Market Packages	HOV and Reversible Lane Management Dynamic Toll/Parking Fee Management Traveler Information (various)
Internal Coordination	Toll setting across highway segments Compatibility of roadway information on affected segments
Peer Coordination	Routing across multiple jurisdictions Fare information across multiple jurisdictions
Cross-function Coordination	Coordinated routing with signal phase/progression Routing to circumvent incidents, speed clearance Transit Prioritization

Table 4. Transit Coordination

Objectives	On-time schedule control Rapid replacement of failed vehicles Rapid dispatch of demand responsive vehicles and efficient routes
NSA Market Packages	Transit Fixed-Route Operations Demand Responsive Transit Operations Multi-modal Coordination
Internal Coordination	Skip-stop, "hot-spares", diversion for schedule adherence
Peer Coordination	Schedule transfer coordination among jurisdictions
Cross-function Coordination	Bus diversion during incidents

2.5 Architectural Needs in California

Interviews were conducted with managers of California Department of Transportation (Caltrans) Management Centers in six of its districts: Sacramento, San Francisco Bay Area, Los Angeles, San Bernardino, San Diego and Orange County (Horan et al, 1997). Interviews were also conducted with TMC managers in the cities of Los Angeles, San Diego and San Jose. In most cases interviews were conducted in person.

The interviews covered four general topics: awareness and participation in the NSA, awareness and participation in standards setting, ongoing projects, and vision for a regional architecture. More specific questions were posed within each category, including identification of impacts of the NSA on ongoing projects, and the geographic and functional scope of future architectures

Overall, the prevailing mood toward architecture in California is optimistic. Many of the coordination issues in Southern California are being resolved or are on the path to resolution, quite independent of the existence of NSA. Ongoing consultant contracts for TMC upgrades are accomplishing greater standardization in software. And most of the interfaces identified in the NSA do not have to be addressed at all in California, at least not in the short run. Nevertheless, major issues remain:

- Gaining efficiency in procurement, maintenance and operation of field devices, with Caltrans HQ facilitating the development of internal standards.

- Developing an architecture for communication and shared operation for city TMC to Caltrans TMC and city TMC to city TMC interfaces, which can be used in "smart corridor" projects, signal coordination projects and meter/signal coordination projects, as well as incident response and management.

3. ARCHITECTURAL IMPLICATIONS OF MULTI-JURISDICTIONAL PROJECTS

To date, the most challenging projects in intelligent transportation have been those that crossed jurisdictional lines. These are challenging technically, because different organizations have installed different computing systems, hardware and software. They are challenging institutionally, because different organizations have different and conflicting objectives, and because there is no straight-forward method for resolving conflicts. In this section, we examine some of the multi-jurisdictional projects planned and underway in California. We examine the lessons learned, and we examine multi-jurisdictional models from other areas. Finally, we propose methods for managing multi-jurisdictional projects in the future.

3.1 Multi-Jurisdictional Projects in California

This section reviews projects in the following areas: (1) emergency response coordination, (2) integrated traffic corridors, (3) intermodal coordination, (4) probe vehicles, (4) ride-sharing projects, (5) ride-sharing, (6) projects targeted at trip generators, (7) traveler information, and (8) wide-area architecture projects. For each project, we provide major participants, an overview of the project and its objectives, architecture and data flows and procedures. In some cases, information is missing because the project is still being planned.

3.1.1 Emergency Response Coordination

These projects entail developing systems for coordinating response to transportation emergencies among police and fire departments.

Coachella Valley All-Agency Radio System
Major Participants: CVAG (lead), CHP, Riverside County, Palm Springs, and Coachella
Status: Has not been funded
Overview: Installation of a multi-agency, 2-way voice radio communications system for Coachella Valley subregion of Riverside County to provide better incident management, emergency response, emergency routing and Mayday support.
Architecture & Data flows: information useful for Mutual aid requests and during natural disasters. Voice is the primary carrier of data and aid requests.
Procedures: TAC and TAC sub committees will establish end-user protocol for priority use under CHP ownership of the system.

Inland Empire InterCAD
Major Participants: RCTC (lead), CHP, SANBAG, CT8, Riverside and San Bernardino County sheriff and fire
Status: Has not been funded
Overview: Network of interconnected public safety agencies in Riverside and San Bernardino counties to facilitate regional incident management by seeking to improve notification times and response to requests for mutual aid among law enforcement, fire and paramedic agencies through interoperability of computer aided dispatch systems.
Architecture & Data flows: Real-time CAD link (not an integration of CAD systems) independent of CAD architectures used by participating agencies. Carrier of information (incident information) will be a common message format and a common agency interface to the system.
Procedures: To be established by a multi agency Task Force.

San Diego Regional CAD Interconnect Project (INTERCAD San Diego)
Major Participants: San Diego PD, CHP, California Division of Forestry and Fire Protection, San Diego FD, Federal FD, Heartland Fire JPA, Escondido PD (and FD) and Oceanside PD (and FD).

Status: Project Phase II in progress. It involves the InterCad system integration to the Kernel. The work is currently focused on modifying the InterCad network (SMDS/PacBell) while the CAD systems are being modified. The Seed design was due in spring, 1998.
Overview: Provide a real-time link between CAD systems in San Diego County, independent of the CAD architectures used by the participating agencies. System independence is achieved through use of a common message management system, standardized message format and a common interface to the agencies. The agencies in turn will maintain translational capability between its internal representation of incident data and the common message format.
Architecture: The components of the InterCAD San Diego include the host CAD interfaces, the message servers, the regional network, an on-line management system for both the messaging system and the regional network and the means to connect the regional networks in San Diego and the Inland Empire. CAD Interconnect network will connect to the regional Transportation Management Center (TMC) through the same message server interface established for other public safety agencies. This will ensure that critical transportation network status information reaches public safety dispatchers and that selected incident data from public safety agencies can be integrated into the TMC data fusion process. The system is intended to connect systems that would otherwise not be compatible with each other.
Procedures: Each agency will receive the incident data in their message system servers through the host CAD system. The specific operational and technical problems are to be solved by a multi-agency task force that has yet to be established. The fire/EMS agencies have already stressed the need to keep track of apparatus status, move-ups, strike team formation, personnel and equipment availability, etc. to adequately manage multi-agency response operations.

Inland Empire Smart Call Box Advanced Weather Warning System and Traffic Census
Major Participants: CHP, Caltrans, CalSAFE, Riverside County Transportation Commission, SANBAG
Status: Has not been funded
Overview: The project will provide basic weather surveillance capabilities on designated highways within Inland Empire. The system will use proven technologies and existing call box infrastructure. The weather detection and reporting capability can provide a source of data dissemination that is otherwise unavailable to travelers in the region. The smart call box traffic census program can use existing call box system with integrated traffic counter devices, existing Caltrans inductive loops and various classification equipment to provide accurate, reliable and timely traffic census and classification throughout Inland Empire.
Architecture and Data Flows: Caltrans District 8 has planned to install environmental sensing units (ESU's) in the Cajon Pass on I-15, SR 138 west of I-15, and the Whitewater Summit area of I-10. These will report directly to the District 8 TMC and include forecast capability. The Smart Call Boxes are proposed to complement to the Caltrans system. These call boxes can be used in areas where full ESU's are planned but not yet deployed, as well as in areas that are not programmed for ESU's. For low visibility sensors, placement at several locations will improve their operational usefulness. The data will flow from the weather sensors (may be housed in the call boxes) and traffic loop detectors to the call boxes that will serve as transmission nodes. The information will be relayed to the Computer Aided Dispatch system of CHP via cellular signals. The system can either transmit the data at periodic intervals or the data can be downloaded in real-time. The weather hazards can then be communicated to the travelers. Commercial Vehicle Operators can also be connected to this system and schedule their fleet accordingly.

Procedures: Pre-designated thresholds for high wind and low visibility are programmed into the system and activate the call box to transmit alerts directly to CHP's CAD system. CHP will respond to the alert according to pre-determined CHP policy. The Smart Call Box Traffic Census system will use the existing call box system with integrated traffic counter devices, existing Caltrans inductive loops and various classification equipment to provide accurate, reliable and timely traffic census and classification throughout the Inland Empire. These data will be used to forecast the traffic growth and also help plan strategies for the district.

3.1.2. Integrated Traffic Corridors

This category includes coordination of traffic management activities between state highways and surrounding arterials within a corridor. Multi-modal coordination is sometimes included as part of these projects.

Fontana-Ontario ATMIS Corridor (West End Corridor)
Major Participants: Caltrans Dist. 8, CHP, Omnitrans, Cities of Fontana and Ontario, SB County, California Speedway etc.
Status: The TAC review is completed. Comments are being incorporated. The final version will be submitted to FHWA by 3/3/98.
Overview: Integrated traffic management and information corridor serving ingress and egress to several important activity centers along I-10 from Ontario to Fontana, including Ontario Airport, Ontario convention center, and Ontario Mills.
Architecture & Data Flows: Between the two TICs and other users; in the form of incident information to ensure that mobile resources flow smoothly between the ends of the corridor.
Procedures: The Fontana TMC will have capacity to monitor and modify key arterial signal patterns

IMAJINE
Major Participants: MTA, Caltrans District 7,
Status: Needs Assessment and Concept of Operations Documents have been finalized. Work is currently focused on users and systems requirements.
Overview: IMAJINE Phase I planned for synchronizing signals on arterial streets with the State Highway System. This involves integrating City and County Traffic Operations Centers with Caltrans Transportation Management Center. Transit vehicles and supervisors will be tracked through the 105 Corridor in coordination with the MTA Bus Priority Pilot Project, and signal timings will be coordinated so as to move transit vehicles through signalized intersections with minimal delay. Additionally, Phase I seeks to coordinate paratransit services with fixed transit services to minimize operating costs of the paratransit fleet. Phase II builds on the first phase by adding an operational interface to rail services in the region. Within the IMAJINE area, RED and BLUE lines as well as METROLINK operate major terminals. IMAJINE phase II will provide the necessary shuttle services between these stations to facilitate end-to-end alternate mode trips and extend the concept further to the north and west to address CVO mobility needs in the Alameda corridor.
Data Flows and Architecture: The Architecture consists of three subsystems: Paratransit/ Fixed transit coordination, Highway/Arterial Signal Synchronization and Bus/Signal priority Coordination. The Data exchanged will be Transit and paratransit schedules and routes, traffic

signal timings, vehicle locations, Arterial Traffic flow information and Freeway Traffic Flow information.
Procedures: Not yet developed.

Los Angeles Smart Corridor
Major Participants: City of Los Angeles, Caltrans District 7, CHP, and LADOT
Status: Smart Corridor is operational
Overview: Joint undertaking of city of Los Angeles, CHP, LADOT, LAPD, FHWA, LACTC and MTA spanning a 5-mile wide and 12-mile long corridor between downtown LA and the San Diego Freeway. Its purpose is to provide corridor mobility by addressing recurring and non-recurring traffic congestion through route diversion, demand control, network balancing and motorist information.
Data Flows and Architecture: The Smart Corridor System/Expert System is composed of SC computer (at Caltrans TOC), Expert Systems computers, SC Workstations at LADOT ATSAC center, LADOT communications center & CHP dispatch center; Expert Systems Workstations at LADOT ATSAC center, Caltrans TOC, & Smart Corridor Computer and intertie with HP and Caltrans' SATMS Operations Center. LADOT, Caltrans, CHP and SCRTD jointly operate the System under coordination of Systems Manager.

LADOT is responsible for operation and maintenance of the data communication network for controlling 353 signals. Caltrans is responsible for operation and maintenance of the trunk network linking the SC Central to other agency control centers. The 14 Color Freeway CCTVs will be maintained by Caltrans and Operated by LADOT and Smart Corridor. 29 Color Surface Street CCTVs will be maintained by LADOT and Operated by Smart Corridor, LADOT, Caltrans and CHP jointly. A joint operation of CHP, Caltrans and LADOT will provide connection from Smart Corridor Traffic condition database to CHP media communications interface. Highway Advisory Telephone will be operated and maintained by Caltrans TOC using 20 toll free lines. Caltrans will operate Freeway entrance ramp meters, freeway connector meters and six CMS on the freeway. 103 Trailblazer and 7 Matrix CMS will be jointly operated on the surface streets by LADOT and Caltrans, with LADOT having a higher hierarchy. The freeway HAR will be jointly operated by Caltrans and Smart Corridor and Surface Street HAR will be operated by Smart Corridor and LADOT.

Procedures: The incident management system (I. M. System) receives incident information from the following sources: Smart Corridor Operators, CHP CAD system, The Smart Corridor Arterial incident detection task and SATMS incident detection algorithms. All such information is converted into Incident Reports (IRs) which are of standardized format and in case of multiple IRs, the system combines them into a IS (Incident Summary), attaches weights to information obtained from different sources and finally asks the operator to confirm the incident. The operator confirms the incident (if available, with CCTV cameras). Upon confirmation, the system suggests a Response Plan based on attributes of the incident, such as time of occurrence, duration, location and type. Each plan has four goals -- Advisory, Traffic flow control, Diversion and On-Site Traffic Management -- and each goal has an associated agency that will execute response plans. Due to the dynamic nature of IRs, the IM system monitors the incident as well as the responses and suggests changes to it. Although all agencies reported above are allowed to submit IRs, only Caltrans and LADOT are allowed to confirm incidents.

SR-91/La Palma Avenue Smart Corridor
Major Participants: City of Anaheim, Caltrans District 12
Status: Functional specifications completed in September, 1996. Under development.
Overview: Decision support system to intertie Anaheim and Caltrans District 12, and assist operators during recurring and non-recurring traffic congestion conditions. CCTV, CMS/Trailblazer signs, traffic signals, traffic flow information and HAR/HAT will be used to control traffic along the SR-91 corridor from SR39 and SR 90.
Data Flows and Architecture: The agencies exchange Video (real time/archived CCTV images), data (graphics, signal timing and other real time traffic surveillance data) and audio (through a fiber optic intertie). City of Anaheim obtains real-time feedback from city traffic signals and detector data from Caltrans District 12. Caltrans District 12 gets CHP dispatch information and City of Anaheim has connectivity to the Anaheim Police Mainframe. The two agencies also exchange transit, construction, maintenance and special event schedules. The two agencies own and operate two separate TMCs. All data gathering sources are owned by one agency or the other. City of Anaheim owns/controls all traffic signals on La Palma Ave, Trailbalzers, CCTVs, HAR and other devices within city's jurisdiction and on La Palma Ave, and the ramps onto freeway 91 that have meters are operated by Caltrans District 12.
Procedures: The TMC at City of Anaheim interfaces with CMS, Trailblazer signs, CCTVs and Traveler Advisory Service and records traffic information. Hence, based on data obtained from one agency, the other agency can either vary traffic signal timings or supply information on Trailblazer signs to overcome congestion. The Decision Support System software will be integrated with pre-planned city and Caltrans activities. The two agencies will also share the use of CCTV cameras, with the highest level in the control hierarchy going to the agency responsible for operation and maintenance of the CCTV cameras. The images will be shared. The agency with lower hierarchy can use Remote Procedure Calls to request control if required. If there is a conflict of interest between agencies at any point, judgement will be used so as to benefit the motorist the most. During special events, Anaheim will give up control of the CCTV cameras under its jurisdiction to Caltrans District 12 since Caltrans operates the TMC 24 hours a day. For Trailblazer signs, an initial library of messages will be set up and the control hierarchy will be similar to CCTV cameras. Both agencies can monitor the signs but only one can operate them at a time. Agencies will request the other to place a message from the library. This will allow agencies to post signs through remote and portable terminals. A similar process is to be followed for HAR. In case of Ramp meters/Traffic signal systems, both agencies may ask the other for manual override to ease congestion on the freeway or surface streets.

SR 17/I880 Silicon Valley Smart Corridor
Major Participants: City of San Jose, Santa Clara County, Caltrans District 4, CHP, Cities of Campbell, Los Gatos, Milpitas and MTC
Status: Under construction
Overview: The Silicon Valley Smart Corridor (SVSC) seeks to coordinate traffic operations along SR-17/I-880 and parallel surface arterials in Santa Clara County by using advanced technologies and real-time system management techniques to help keep all transportation facilities within the Highway 17/I-880 operating at maximum efficiency. SVSC stresses both mode and route diversion. Route diversion will only be used in case of incident congestion such as major accidents and not for routine or recurring. To facilitate ridesharing, smart parks will

provide park-and-ride along with ITS technologies and special conveniences to attract motorists, such as HAR, electric vehicle charging area, in-vehicle information, CMS, and information kiosks. Smart Parks will serve as anchor points for transit services.
Data Flows and Architecture: The corridor contains freeways, expressways, surface streets, bus routes and LRT lines that are owned and operated by several different agencies. The Smart Corridor involves cooperation between agencies that operate different transportation facilities to share collected data amongst all participating agencies. The actions of any agency are coordinated with and known to all others. This results in the traveler having a single source of information about all facilities and travel options. Information is disseminated via changeable message signs and Highway Advisory Radio and traffic signals will be synchronized. Information will be obtained from CCTV cameras which will be transmitted via fiber optic and some leased telephone lines.
Procedures: The agencies will exchange real-time data on traffic counts, facility status, incident information, equipment status, planned events and operational stages. The data exchange network will enable basic commands to be sent between agency systems as well as data. This enables, for example, the implementation of traffic responsive signal coordination across jurisdictional boundaries, involving detector data being collected from all involved signal systems and the selected timing pattern number sent back to the system for implementation, In addition, a fiber optic network will enable agencies to view each other's closed circuit television cameras when desired. The communication network is also shared to provide maximum reach at minimum cost.

<u>3.1.3. Intermodal Coordination</u>

These projects focus on the coordination of transportation services among two or more transportation modes.

Integrated Railroad Crossings
Major Participants: MTA (lead), LADOT
Status: Has not been funded
Overview: MTA is proposing a three phase project to demonstrate ATMS systems and new technologies currently being deployed in cities throughout US for management of street and freeway traffic flows, at highway/rail grade crossings in an urban area LRT corridor. The first phase will implement health-monitoring systems at Metro Blue Line crossings. Health monitoring of the crossing protection and traffic control equipment at highway-railroad grade crossing is done independently for each system. Safe operation of the system is dependent on both systems functioning together in a coordinated manner. The second and third phases of the project will demonstrate two models, showing how capabilities of modern street and rail traffic control systems can be effectively brought together at grade crossings, both to improve public safety and to enhance traffic flows. Adaptive traffic preemption strategies and variable message signs will provide advance warning and motorist information.
Architecture & Data Flows: Not yet defined.
Procedures: Not yet defined.

Orange County Transit Probe
Major Participants: OCTA(lead), Caltrans, Santa Ana, Anaheim

Status: Began operation in May of 1998
Overview: The project has installed GPS receivers on 15 buses, running on three lines in Anaheim and Santa Ana. Data from the buses are being used for schedule control, and to develop estimates of roadway congestion. Congestion estimates are provided to the Cities of Anaheim and Santa Ana, and to Caltrans District 12.
Data Flows and Architecture: Exception data are communicated over OCTA's radio network, indicating when a bus has fallen behind schedule or congestion is observed. These data can be viewed within the STARS software application, developed by 3M Corporation. Data are uploaded and downloaded when vehicles pull in and pull of the yard via a wireless local-area-network. These data include schedule information and more detail on schedule performance, allowing for analysis of historical schedule performance data. The STARS application is being provided to Anaheim, Santa Ana and Caltrans District 12 to view the data.
Procedures: Operational procedures are being developed.

San Diego Intermodal Transportation Management and Information System
Major Participants: Caltrans 11,SANDAG,CHP
Status: Contract has been executed, and the first monthly meeting occurred January, 1998. The project activities are divided and focused by several subgroups by function. The work will initially focus on the needs assessment and users requirements.
Overview: This project proposes improving the existing Caltrans single mode TMC operating system architecture to one that supports regional intermodal and multimodal functions, divided into two phases, including the development of user requirements, systems requirements, interface requirements and high level design, prototype implementation, prototype operations, evaluation and final design implementation.
Data Flows and Architecture: Caltrans' Southern Districts have adopted and documented an open systems profile to ensure that all TMC systems are based on a robust architecture that complements system-to-system integration. It is proposed to have interconnection between various operating systems and the scope of the second phase of this project may include improvements in the operating systems of the other regional operators.
Procedures: Since each of the agencies involved in the project has a vision of potential intermodal and multimodal relationships, and there is no consensus, the roles and responsibilities have not been fully defined.

3.1.4 Probe Vehicles

These projects entail using vehicles to collect information on traffic conditions, and sharing that information among agencies.

Inland Empire Motorist Aid Patrol
Major Participants: SANBAG (lead), CHP
Status: Not yet funded
Overview This proposal recommends a public/private partnership funding program for a motorist aid patrol along the 110 mile stretch of I-15 between Barstow and the California/Nevada State line. Data from the patrol would support traffic data collection. This patrol area lies within San Bernardino County.
Archictecture & Data Flows: Not yet defined

Procedures: Not yet defined

3.1.5 Ride-Sharing

This project entails sharing information between ride-sharing agencies to provide more complete ride-match services.

Inter-Regional Rideshare Data Base Linkage
Major Participants: CVAG (lead), CHP, Riverside County, Palm Springs, SCAG, SANDAG
Status: SCAG is incorporating the TAC comments and is pursuing SANDAG's approval on the final work plan. The final work plan was to be submitted to FHWA in spring, 1998.
Overview: This project will link the rideshare and transit databases maintained separately by SCAG and SANDAG, in order to provide rideshare information to intercounty Priority Corridor travelers and cross county commuters. Execution of this project will allow each agency to provide travelers and other organizations/employers/agencies with transit itineraries, rideshare partner matchlists, and vanpool information and coordinate the electronic exchange of transit and other rideshare information throughout Southern California - from Santa Barbara to San Diego.
Data Flow and Architecture: Not yet developed.
Procedures: Not yet developed.

3.1.6 Targeted Projects (Major Trip Generators)

These projects entail coordination of transportation to and from major trip generators, including stadiums and airports.

John Wayne Airport Area Coordinated Management
Major Participants: John Wayne Airport,CT12,Orange County Irvine,Newport Beach
Status: Not yet funded
Overview: This project consists of a coordinated traffic management and traveler information project in the John Wayne (JWA) airport area. This area encompasses I-405 and SR-55 freeways and associated transition and exit ramps along the main street, MacArthur Blvd, Michelson drive and Campus Drive in the vicinity of the airport. The system would utilize parking availability via the real-time parking access system along with Caltrans and local monitoring of airport installed cameras. The system would disseminate the information via existing freeway CMS, New Arterial CMS and finally Travel ITP. Traffic management will include the monitoring for delays in the field.
Data Flows and Architecture: Not yet determined
Procedures: Not yet determined

San Diego Jack Murphy Stadium ATIS Project
Major Participants: City of San Diego, Caltrans
Status: Work plan approved. Contract Phase II has been executed. Under this phase, the communication links will be developed among the City's TMC, Caltrans TMC and the Stadium's TOC.

Overview: This project involves design and implementation of an ATIS project which will provide motorists with accurate and timely information about current traffic conditions on arterials and freeways. This will allow motorists to make intelligent and informed decisions regarding their route and time of travel before and during the trip.
Data Flows and Architecture: Not yet determined
Procedures: Not yet determined

3.1.7 Traveler Information

These projects entail creation of systems for disseminating information to travelers where information is collected by multiple public agencies.

Commercial Vehicle ATIS
Major Participants: CTA, Caltrans, SANBAG, SCAG
Status: The overall scope was submitted to FHWA and has received approval. The draft work plan is being reviewed by the TAC. The final will be submitted to FHWA in spring of 1998.
Overview: This project will allow commercial vehicle operators and dispatchers to receive notifications of roadway conditions and incidents so that they can manage the movement of freight more efficiently and avoid traffic congestion and delay wherever possible. Travel and route information related to CVO operation will be sent out using an FM subcarrier from the multi-regional TMC network. Drivers and dispatchers will receive a message on a vehicle or office receiver when there is unusual traffic congestion or an incident on a route in which they are interested. Depending on the level of interest and availability of information, messages could also be provided on international border crossings, port access and airport access.
Data Flows and Architecture: Not yet developed
Procedures: Not yet developed

Freeway Incident Response Services Tracking (FIRST)
Major Participants: MTA and CHP (Lead), Caltrans, LA DOT, LA County Emergency Operations Center, LA County Coroner, LAPD, LAFD,
Status: Under development.
Overview: This project plans to improve access to the proprietary CHP computer aided Dispatch (CAD) system so that freeway incident information can be distributed. It will provide an opportunity to distribute incident information to allied agencies in Los Angeles County; enable agency-to-agency transfer of traffic/incident information, offer real-time incident information to Metro Freeway Service Patrol Fleet, CHP field Officers and other MTA related bus/rail operations. It will also provide system security while improving data access and information sharing. Additionally, FIRST will attempt to improve incident reporting and tracking for statistical modeling to measure and evaluate congestion models and incident response time.
Data Flows and Architecture: FIRST is being developed by MTA and installed at CHP. The information dissemination to the other agencies will be via dedicated telephone lines, intranet web pages and to the general public through media (TV and radio).
Procedures: Not yet developed

Integrated Modal-Shift Management Tool

Major Participants: Caltrans 7(lead), MTA, SCAG, LAC Bus Operators Subcommittee, CHP, City of Los Angeles, County of Los Angeles, SCAQMD and Ventura County Transportation Committee.
Status: Work plan approved. Contract execution pending.
Overview: This project proposes integration between advanced-traffic-management-systems (ATMS) and ATIS through a real time cross jurisdictional modal shift management tool that provides travelers within Los Angeles and Ventura counties with real-time information related to incidents and potential alternate routes. These will be detailed relative to specific incident profiles and specific incident locations. It will complete an integrated system that will both combine the existing systems as well integrate traveler information services with the Caltrans District 7 ATMS. One of the key objectives of this project is to develop an integrated, distributed system that will maintain each agency's control, ownership and management of their respective data, while still allowing the sharing of the information throughout the counties and corridor.
Architecture & Data Flows: The data and information planned to be included in this system are: (a) Freeway and Surface street congestion, closures, detours and maintenance, (b) Alternate modes of transportation (bus and rail schedules) and analysis for the users on mode cost, route alternatives, timing and availability for handicapped travelers, (c) Major incident locations with alternative routes and modes to lessen both individual travel time as well as the impact of the incident overall, and (d) Additional private sector information including restaurants, hotels, gas stations, real time route guidance/navigation information in recognition that once drivers are diverted they will need landmark and services information.
Procedures: Not yet developed

Orange County TravelTip
Major Participants: OCTA (lead), Caltrans, Transit agencies (OCTA, MTA), Cities and CHP
Status: System management, integration, and outreach & marketing efforts in progress. System integration is currently focused on finalizing the system design report.
Overview: This projects provides for information dissemination through a variety of channels, along with implementation of a high bandwidth wide area network for transportation agencies in Orange County that would provide for intragency communication throughout the County without the recurring costs and incompatibility of individual point-to-point leased lines. The WAN would allow for the exchange of freeway and surface street traffic data between Caltrans, local agencies and other Corridor Showcase partners, along with TravelTIP data, ramp meter rates and status, CMS as well as traffic signal timing and status.
Data Flows & Architecture: Data will be gathered from Transit agencies, Caltrans, CHP, Transit probes, Weather Bureau, Airlines and various cities and disseminated to WWW, Bulletin Board Services, Rideshare Matching Agencies, Yellow Pages, Value Added Resellers and map vendors and directly through Community Access TV, HAR, Kiosks, Media. Since the communication systems of all the numerous agencies are heterogeneous, the National Transportation Control/ ITS Communication Protocol proposed Common Object Request Broker Architecture (CORBA). CORBA is a software architecture that establishes a four-element communication framework: Object Request Broker, Object Services, Common Service and Domain Objects. ORB is middleware that establishes the client server relationship of objects. Object Services are domain-independent services that are used to support distributed processing.

Common Services are implemented as CORBA objects on top of ORB (e.g. user interface and document management). Domain Objects are the application specific interfaces defined in terms of CORBA's IDL for the domain, which in this case is the ITS domain (e.g. incident detector, incident, incident responder, congestion detector, variable message sign)
Procedures: Not yet developed

Los Angeles/Ventura Regional Advanced Traveler Information System
Major Participants: MTA (lead)
Status: The TAC review is completed. Comments are being incorporated. The final version was scheduled to be submitted to FHWA in spring of 1998.
Overview: This project proposes a partnership among various public agencies and, in the future, the private sector to deploy a sustainable ATIS for Los Angeles/Ventura region. This project uses the showcase architecture to merge information from various sources, including transportation management systems.
Architecture & Data Flows: Not yet developed
Procedures: Not yet developed

San Diego Regional Advanced Traveler Information System
Major Participants: SANDAG (lead)
Status: Has not been funded
Overview: The San Diego ATIS project proposes a partnership with the private sector to deploy a sustainable ATIS for the San Diego region. This project uses the Showcase architecture to facilitate the required merging of information from information from various sources, including transportation management systems.
Architecture and Data Flows: Not yet developed
Procedures: Not yet developed

TransCAL
Major Participants: Caltrans
Status: Operational as of 1997
Overview: TransCAL provides traveler information in the I-80 corridor between the Bay Area and Lake Tahoe. The project includes information dissemination through a traveler-advisory-telephone system, along with testing of various navigation devices and kiosks.
Architecture and Data Flows: The system was developed by TRW/ESL and is modeled after TravInfo.
Procedures: No specific Procedures are provided for responding to information. Information is provided to travelers, who choose their own responses.

TravInfo
Major Participants: MTC, Caltrans, and CHP
Status: Operational as of September, 1996. Test period continues until fall of 1998.
Overview: TravInfo integrates information from a variety of sources, and disseminates the information to travelers via a traveler-advisory-telephone-system and through links to information-service-providers. TravInfo provides real-time information on highway speeds and incidents, and static information on transit services.

Architecture and Data Flows: All information passes through the traveler-information-center housed in Caltrans District 4 and operated by Metro Networks. Operators review incident logs on the CHP computer-aided-dispatch, and enter data into the TravInfo database. Significant incidents are also voice recorded by access through the TATS. The database can be accessed by "registered participants", who can disseminate information to end-users. Currently, Etak and Maxwell Laboratories provide web page access. TATS phone callers select options from a menu, allowing them to hear the recorded messages, or allowing their calls to be routed to transit agencies or ride-sharing.
Procedures: Procedures have been developed for determining which incidents should be entered into the database. No control actions are taken by TravInfo, and information is simply made available to the public.

Real-Time Traffic Information For Truck Stops
Major Participants: Caltrans, Agencies in Inland Empire
Status: Has not been funded
Overview: This project involves installation of Traveler Information Kiosks, which will display Caltrans' real time freeway congestion maps at four trucking terminals/truck stops in Inland Empire.
Architecture & Data Flows: Not yet developed
Procedures: Not yet developed

3.1.8 Wide-area System Integration

These projects entail creation of general-purpose systems for coordination of transportation services or for sharing information among agencies.

Corridor-Wide Advanced Transportation Management System
Major Participants: Caltrans 7(lead), CT 8,11,12
Status: The TAC review is completed. The final work plan is being prepared and will be submitted to FHWA in spring of 1998.
Overview: This project will link Regional Transportation Management Centers throughout the Southern California Priority Corridor area to coordinate regional traffic movement during recurring and non-recurring incidents, as well as to assist in disaster relief. The vision of showcase is to integrate all modes and all roads into a system of systems by leveraging the existing transportation systems infrastructure in Southern California against a number of strategic new systems initiatives.
Architecture & Data Flows: Not yet developed
Procedures: Being developed as part of individual showcase projects.

Corridor-Wide Advanced Traveler Information System
Major Participants: Caltrans
Status: The TAC review is completed. The final work plan is being prepared and will be submitted to FHWA in spring of 1998.
Overview: This project plans development of an operational framework for a comprehensive traveler information system across Southern California Priority Corridor. It will address issues

such as coordinated deployment, operations, management, maintenance, upgrades for traveler information, and data availability throughout the corridor.
Architecture & Data Flows: Not yet developed
Procedures: Not yet developed

Corridor-Wide Advanced Public Transportation System
Major Participants: MTA
Status: Has not been funded
Overview: This project will provide the means to coordinate Regional Transit Agency operations throughout the Southern California Priority Corridor Area as well as the instrumentation of existing passenger/commuter rail for the purposes of tracking train arrival and departure times at Intermodal Passenger Transfer Points. Additionally, it will assist in providing real-time traveler information to the public through dissemination devices implemented under a future project.
Architecture & Data Flows: Not yet developed
Procedures: Not yet developed

Corridor-Wide System Integration
Major Participants: All showcase stakeholders
Status: The draft work plan has been prepared by NT&R and is being reviewed by the TAC. The final version will be submitted to FHWA by 3/3/98.
Overview: This project seeks integration of over fifty projects within the Southern California Priority Corridor into the Showcase "system of systems." Within these fifty projects, the corridor will deploy an architecture that is compatible with the National System Architecture guidelines, establishing 19 market packages over a corridor-wide basis. This project requires a proven systems engineering service to ensure a structured approach to integration, a consistent configuration management system, establishment of interface standards and protocols and consistency in deployments across the corridor.
Architecture & Data Flows: Not yet developed
Procedures: Not yet developed

Orange County Model Deployment Initiative
Major Participants: OCTA, Caltrans, and CHP
Status: The TAC review is completed. Comments are being incorporated. The final version will be submitted to FHWA in spring of 1998.
Overview: This project is intended to provide a mechanism for communicating information among projects and agencies in Orange County.
Architecture & Data Flows: Not yet developed
Procedures: Not yet developed

San Diego Regional Traffic Signal Integration
Major Participants: SANDAG (lead), CT 11,County of SD, and various cities
Status: The TAC review is completed. The final work plan is being prepared and will be submitted to FHWA in spring of 1998.

Overview: The project proposes initial deployment or an integrated traffic signal control system architecture. It uses showcase kernel as the tool to facilitate this integration. The regional architecture proposes the support of various traffic signal operating systems.
Architecture & Data Flows: Not yet developed
Procedures: Not yet developed

Showcase Kernel
Major Participants: Involves all Showcase members
Status: Funding in process
Overview: This initiative is designed to deliver a seamless inter-modal Transportation Management and Information System across entire Southern California Priority Corridor with the following functionality:

- Initial point of integration for the existing infrastructure and Showcase projects to start with, ensuring success of Corridor and modal wide integration of Transportation Management function.
- Initial target location for all sources of ATIS information for the purpose of consolidating traveler data, enabling migration towards one-stop shopping for multimodal trips as early as possible.
- Facilitate electronic communication for all parties interested in development of seamless ATMIS in the Corridor.
- Provide Internet capability that posts all relevant data from all modes, all roads and improvement initiatives, and provides electronic survey capability as well as allow real-time access to all Showcase initiatives.

Architecture & Data Flows: Not yet developed
Procedures: Not yet developed

3.2 Lessons Learned from Smart Corridor and TravInfo

Smart Corridor and TravInfo are the most advanced multi-jurisdictional projects in the state, and both provide lessons for the future.

3.2.1 Smart Corridor

One of the biggest challenges in developing Smart Corridor was creating the policies for jointly operating the facility under the cooperation of the City of Los Angeles, Caltrans and other agencies. These policies are documented in "Operation Planning Element" of the project (JHK, 1993). As general themes, the document identifies which department has authority over decision making and use of equipment under well defined circumstances, and defines action steps required for possible events. The Smart Corridor System acts like a third party that integrates information between agencies, rather than providing direct access to another agency's systems. Other key features are as follows:

- The Agency is which the incident is first reported is appointed the incident manager. The incident manager agency remains the incident manager agency for the life of the incident. (For example, if a highway incident is almost cleared and causes backup problems on surface streets, the Caltrans incident manager remains in charge.)

- The owner of a CCTV camera should be the top priority user. Other agencies who wish to use the other agency's camera must make certain that it is idle.

- An operating agreement is recommended to "allow the use of each Agency's CMS for management of congestion and incidents on a facility within Smart Corridor irrespective of which agency has jurisdiction over the facility."

- Agencies can input information regarding planned events at their discretion.

Separate from this document, LA DOT and Caltrans have agreed that certain routine actions could be taken by within another agency's jurisdiction when the other agency's TMC is closed down. This might include changing a CMS message or choosing a pre-programmed signal plan. However, this concept does not appear to have been executed.

No evaluation has been completed on the Smart Corridor project. Our conversations with Los Angeles Department of Transportation indicate that the system is used extensively for managing their signal network, and was also used for monitoring traffic and creating control responses. Our conversations with Caltrans indicated that the system was used infrequently there. The Smart Corridor system does not appear to be used extensively for the purpose of cross-jurisdictional coordination. Nevertheless, the project provides a good starting point for creating cross-jurisdictional operating agreements.

3.2.2 TravInfo

The institutional evaluation showed tremendous obstacles to creating and operating centralized information systems (Hall, 1998):

- Centralization may require a new organization, with significant time burdens
- A consensus based partnership is slow and ineffective at making critical decisions (adding to both time and cost)
- Centralization disconnects the information provider from the end user (as the owner of the information does not communicate directly with the ISP)
- A publicly funded project seems ineffective at anticipating the needs of consumers for traveler information

The institutional evaluation further concluded that (Hall, 1998):

- Government agencies should be extremely cautious in entering into system development contracts, and should first consider whether objectives can be met through other contractual vehicles, such as a service contract. This would place the contractor in a better position to integrate government data sources with private sources (especially aircraft surveillance) and to provide cost-effective synergy with radio traffic reporting.

- Information centralization projects should be initiated only when there is clear evidence that centralization provides added value to travelers or system performance. In light of available

Internet technologies and the delays and costs of centralization, distributed systems, in which individual agencies retain responsibility for their own data, should be the first choice. Also, in light of the need for nationwide services, it is highly questionable whether government should take on this role.

- Information projects should stick to at least one aspect of TravInfo's concept: traveler information systems are best justified when valuable information within a government agency can be made accessible to end users through minimum public investment. Unfortunately, the high-payback/minimal investment philosophy on which TravInfo was originally founded vanished.

- In the future, it would be best to follow an information pull policy, similar to that of the California Highway Patrol. When private entities request information that has considerable public value, make cost-effective investments to simplify access. On the other hand, do not make costly investments in systems to push information on the private sector, in anticipation that the information will be desired.

3.3 Models for Coordination From Other Sectors

3.3.1 Fire Agencies

There is longstanding precedent for fire departments to provide aid to each other in case of emergency. Today, these agreements take the form of "Mutual Aid" and "Automatic Aid", which formalize in advance the conditions under which one department will aid another, and the nature of the aid provided. Such agreements are commonplace today in California, in large measure in response to the large brush fires that occur in the state, consuming and exceeding the fire fighting capacity of any individual jurisdiction. We use, as an example, automatic aid agreements within the Los Angeles Fire Department.

Steps The agreements between Los Angeles City Fire Department (L.A.F.D.) and fire departments of other cities take place as follows:

At first, there is a meeting with the other agency and a study is conducted of the proposed area of response of both agencies. Then, based on a sample or *Boiler Plate* draft or sample Mutual Aid Agreement, a new agreement is drafted which also depicts on a map, the area to be covered in the agreement. On approval by both the City Attorneys and review by Chief Engineer's staff, this is given to the Operations Control Division (OCD) that is the dispatching authority. The Dispatch Section is responsible for the receipt of emergency and non-emergency calls for help from the public via the 911 telephone system and the control and dispatch of all Department emergency resources. During Fiscal Year 1993-94 for example, the Dispatch Section processed over 645,993 incoming calls, of which 523,965 were emergency calls, culminating in dispatching of fire apparatus and rescue ambulances to over 309,704 emergency incidents.

On approval, the Chief presents the final document to the Commission, which then passes it forward to the City Council on recommendation by the Chief that approval be sought.

The city clerk assigns a Council File Number and, after approval is received, the City Attorney reviews changes, if any that have been made. A starting date is provided to OCD. The primary means of communication used are Telephone and Wireless Radio.

All the required signatures are obtained and copies are distributed to the affected battalions and divisions, and also to the Bureau of Emergency Services. The Bureau of Emergency Medical Services, under command of the Chief Paramedic, is responsible for the overall planning, organizing, and directing of the Department's Emergency Medical Services. The Department maintains a total of 52 Paramedic ambulances, 11 Paramedic engine companies, and 13 EMT ambulances. Uniformed EMS personnel and rescue ambulances are assigned to one of six EMS Districts under the supervision of a platoon-duty EMS District Captain. EMS Bureau resources responded to over 230,000 EMS incidents during Fiscal Year 1993-94. An additional copy is placed in the Mutual Aid Agreement Book.

Content The Agreement recognizes that it is in best mutual interest to provide the most expeditious response to suppress fires and provide other emergency assistance.

The chief components of a mutual aid agreement are (Los Angeles, no date):

1. Services to be provided by the City of Los Angeles Fire Department and the other fire agency: The limits within the cities are marked and the "agreed upon" response is defined. Each individual agency also designates which fire Stations/battalions will respond to a certain emergency call (in terms of nature of emergency and physical location). In fact, since there is public benefit, the LAFD units may respond even if it is not covered in the agreement, if personnel and equipment are available.

2. Dispatch of Services by the Fire Departments: The designated authority within the other city's fire department is identified and the procedure is documented. Usually an alarm is simultaneously conveyed to the LAFD dispatcher, who in turn dispatches the agreed-upon response.

3. Incident Command: A standard policy is inserted in all agreements:

   "In those instances where the aiding Department arrives before the jurisdictional Department, the aiding Department will take the necessary action dictated by the situation. However, it is assumed that the jurisdictional Department will arrive shortly after the arrival of that aiding Department. Overall command of the incident will be assumed by the jurisdictional Department upon its arrival at the scene. The aiding Department's personnel will remain under the command of the highest ranking officer of the aiding Fire Department at the incident. The resources of the aiding Department will be released from the scene as soon as practical by the jurisdictional Fire Department." (Los Angeles, no date).

4. Future Revisions: Since the agreement provides mutual benefit to both parties, the fire chiefs of both cities are authorized to make changes to the agreement to provide mutual aid to both parties.

5. Administration: Details on the amount and type of assistance to be dispatched, methods of dispatching (through the dispatch center of both cities for example) and communication, training programs and procedures, methods of requesting aid, names of person authorized to send and receive such requests and lists of equipment and personnel to be utilized on both sides are enumerated.

6. Usually no compensation is involved in this agreement since the respective covenants assume a reciprocal and mutually beneficial agreement.

7. Period of Agreement: Usually there is no termination date to such agreements.

3.3.2 Electricity Generation and Distribution

Electric utilities perform two major functions: Power Generation (through Thermal, Hydro-Electric, Geo-Thermal and Nuclear Power plants) and distribution of this power to retailers and consumers over transmission lines.

The power networks in United States have been linked together in ten NERC control areas;

1. East Central Area Reliability Coordination Agreement
2. Electric Reliability Council of Texas
3. Florida Regional Coordinating Council
4. Mid-Atlantic Area Council
5. Mid-America Interconnected Network
6. Mid-Continent Area Power Pool
7. Northeast Power Coordinating Council
8. Southeastern Electric Reliability Council
9. Southwest Power Pool
10. Western Systems Coordinating Council

The WSCC, which includes California and most of Western US and Canada, has both public and private utilities as members (Table 5)

Agreements Electric utilities have established a hierarchical set of agreement to coordinate the generation and transmission of electricity among inter-connected networks.

1. Purchase agreements
2. OASIS:
3. Mutual Assistance Agreements.
4. Inadvertent flow restoration.

Purchase agreements are pre-planned and long-term; OASIS is pre-planned but short-term; mutual assistance agreements are pre-planned responses to network incidents, and are executed in real-time; flow restoration occurs on a continuous basis. These are described more fully below:

Table 5. Western Systems Coordinating Council Members

Arizona-New Mexico Area	
AZPS	Arizona Public Service Company
EPE	El Paso Electric Company
IID	Imperial Irrigation District
PNM	Public Service Company of New Mexico
SRP	Salt River Project
TEP	Tucson Electric Power Company
WALC	WAPA - Lower Colorado

California-Southern Nevada Power Area	
PASA	City of Pasadena
CFE	Comision Federal de Electricidad
LDWP	L.A. Dept. of Water & Power
NEVP	Nevada Power Company
PG&E	Pacific Gas & Electric Company
SDGE	San Diego Gas & Electric Company
SCE	Southern California Edison Company

Northwest Power Pool Area	
BPA	Bonneville Power Administration
BCHA	British Columbia Hydro & Power
CHPD	Chelan County PUD #1
DOPD	Douglas County PUD #1
GCPD	Grant County PUD #1
IPC	Idaho Power Company
MPC	Montana Power Company
PACE	PacifiCorp - East
PACW	PacifiCorp - West
PGE	Portland General Electric Company
PSE	Puget Sound Power & Light Company
SCL	Seattle City Light
SPP	Sierra Pacific Power Company
TCL	Tacoma City Light
TAUC	TransAlta Utilities Corporation
WWPC	Washington Water Power Company

Rocky Mountain Power Area	
PSC	Public Service Company of Colorado
WAUC	WAPA - Colorado Missouri
WAUGPW	WAPA - Upper Great Plains - West

1. **Purchase agreements**: All electric utilities do not have generation capacity equal to demand. The generation costs for each utility may not be the same due to the local regulation, source of power (Thermal, Nuclear, Hydroelectric etc) and due to variable transmission losses which can vary widely, ranging from 5-12 %. Also, rates change every hour depending on power consumption. Thus it is profitable for power companies to buy from each other. The Los Angeles Department of Water and Power, for example, purchases excess Hydro-power from Bonneville Power (BPC) during the daytime under a purchase agreement. During evenings, another contract is in place between the same companies in which LADWP sells electricity to BPC. The transmission route, when it passes from several networks, is optimized for least cost (transmission cost and losses), and stability.

2. **OASIS**: OASIS is an online tool for WSCC member utility companies to pool their transmission resources so that all of a company's unused *transmission* capacity can be used by other companies on a temporary basis. OASIS is for a shorter duration, ranging from a day to a month. The transmission line availability is visible on the worldwide-web and the *reservations* can be made as late as one day in advance. In case of emergencies, the dispatcher has authority to make and execute contracts over the phone. This arrangement is seen as temporary in nature. Once deregulation is implemented, all electricity networks in California will be required to pool their transmission assets and the prices for such services will be based on the costs to the company as opposed to a wider fluctuation based on the regulated profitability requirements.

3. **Mutual Assistance Agreements**: The Utilities within a control region (WSCC for example) may have parallel transmission resources between two points. Under the Mutual Assistance agreement; *in case of a major incident all the remaining transmission capacity is to be shared by the utilities in the ratio of their holding before such event occurred.* For example, suppose that there are transmission 10 lines of transmission between two cities; out of which 6 are owned by LADWP and 4 by Southern California Edison. Due to an act of Nature, if 5 of these lines are put out of operation, the remaining lines are to be shared by the companies in the ratio of 3:2 by LADWP and SCE even if all the 5 lines knocked out were LADWP or four of SCE and one of LADWP.

4. **Inadvertent flow restoration**: All the utilities in WSCC grid generate and transmit electricity at 60 Hz. As part of the WSCC agreement, each company is required to keep a certain amount of generating capacity in reserve. The reserve takes two forms: spinning reserve and non-Spinning reserve. Spinning reserve is the reserve that is online and being continuously generated. Non-spinning reserve is offline but available for consumption on a short notice (about 10 minutes). Each company is required to maintain enough in reserve, such that the sum of which equals the largest single power generation unit. In case two companies jointly operate a power plant, they are required to maintain enough reserve that equals the largest shared power generation unit. Moreover, each utility should have at least 7% of total thermal generation online and 5 % of their hydro-resources online and take the higher of the two, out of which 50% must be spinning reserve. This brings about a loss in economy but increases reliability. At points where two networks interface, several

parameters are monitored: imbalance, under voltage, over current, negative sequence protection, loss of synchronization, etc. This is sampled by transformers and compared with all the three phases. If any network is seen to be out of *sync,* all the other networks will automatically provide their reserve power to compensate for the loss of power. If, however, the affected network seems to be collapsing, then under the *Frequency Separation Protocol,* it will isolate itself from the rest of WSCC grid via the auto preset controls in order to protect the rest of the grid. This also occurs on a regular basis when the Switching/Measurement stations between the networks measure the net flow of current continuously and apply a charge later. This charge changes almost every hour, since the need for electricity is not the same in different parts of the grid at different times.

Agreement Creation As an illustration of how these agreements are established, the Federal Energy Regulatory Commission proposed that public utilities set up information networks to give wholesale sellers and purchasers of electricity equal access to information on transmission availability and prices in 1995. These are known by several names: "real-time information networks" (RINs), "Open Access Same-time Information System" (OASIS) or "Transmission Systems Information Networks" (TSINs)".

Two working groups came about to create a consensus on the "How" and "What" of the Information Networks. NERC facilitated the efforts of the "What" Working Group, as it came to be called. It was their job to reach consensus on the information that should be included on a TSIN in order to fulfill FERC's purpose. The effort resulted in a report, submitted to FERC on behalf of the industry. A sister to the "What" Working Group is the "How" Working Group. Facilitated by Electric Power Research Institute (EPRI), the how group focused on the technical details of developing a TSIN and providing for the functionality described by FERC. The "How" Working Group efforts also resulted in a report submitted to FERC.

FERC acknowledged the efforts of both the "What" and "How" Working Groups when it released its Notice of Proposed Rulemaking on real-time Information Networks and Standards of Conduct on December 13, 1995. Finding both processes representing broad consensus of all segments of the electric power industry, FERC adopted many of the technical parameters suggested in the "What" and "How" reports. Both the "What" and "How" groups provided comments to FERC on its NOPR on February 5, 1996.

FERC's Final Order 889, announced on April 24, 1996, requires utilities to establish electronic systems to share information about available transfer capability. The order also dictates standards of conduct. Final Order 888 was announced the same day and addresses open access and stranded cost issues.

3.4 A Model for Inter-jurisdicational Coordination in Transportation

The best examples of inter-jurisdicational follow a simple three step pattern:

1. Development of model agreements and policies

2. Negotiating a specific agreement covering participating parties

3. Execution of that agreement in practice

3.4.1 Model Agreements

A model agreement provides "boiler plate" language that could be adopted within any multi-jurisdictional project of a given type, or any universal policy that governs all activities of a given type. They can be developed in much the same way as a standard (see Section 4). An ad hoc committee is formed under the auspices of a recognized organization, such as Institute of Transportation Engineers or perhaps Caltrans, with a single objective of developing a specific type of model agreement. A negotiation and working group process is set to develop the agreement within a set schedule, after which the agreement is submitted to balloting by involved parties. The agreement is accepted if it passes with a super-majority (e.g., 2/3).

3.4.2 Negotiation of Specific Agreements

The model agreement has no force until it is adopted by a multi-jurisdictional project. Organizations entering into an agreement use the model agreement as a starting point, keeping the portions that are relevant and striking others. Specific terms are added to localize the agreement. Once the agreement is finalized at the staff level, it is submitted to higher levels of the organization for formal approval.

3.4.3 Execution

The negotiated agreement provides the structure for how the system is operated on a day-to-day basis. The agreement is only meaningful if all involved parties adhere to its terms, and use it to improve their coordination.

3.4.4 Areas Where Model Agreements Are Needed

We provide three examples of where model agreements would be beneficial. These are used to illustrate how concepts from organizations can be applied to meet the needs of transportation.

Incident Management Fire districts have a long history of providing aid across jurisdictional boundaries. They have established a simple and effective command and control structure that enables different agencies to work together toward a common objective. A fire department never loses command over incidents within its own jurisdiction (except temporarily, if units have not yet arrived), and a fire department never loses command over its own personnel. A similar command structure was eventually adopted by Caltrans and LA DOT within the Smart Corridor, and should serve as the model for future cross-jurisdictional projects in transportation. The agreement can further specify geographical areas of coverage, the types of incidents that would initiate a cross-jurisdictional response and the magnitude of the response (as has also been done in fire departments).

Flow Management During Incidents The electrical power industry has a simple policy for responding to network incidents, that of sharing remaining capacity in proportion to base level capacity. Networks respond automatically by diverting the traffic of electricity. A simple guideline of this type would be highly beneficial in "Smart Corridor" type projects, where several roadways provide capacity in parallel.

Real-time Network Interfaces In the future, transportation networks will become more like electrical networks, in which the system is continuously monitored and controlled from management centers. However, even the electrical power industry does not attempt to centralize management across jurisdictions. Instead, each agency manages its own network, within prescribed guidelines that prevent failures at network interfaces. The system is controlled through a combination of interface monitoring stations, real-time pricing, and safeguards that ensure that problems in one jurisdiction do not spill over into another. A similar model could and should be developed in transportation. Such an approach could begin with bilateral agreements, but may best be implemented through broader networks that ensure the stability and reliability of the network as a whole. By this approach, the transportation grid can be monitored automatically, with human intervention limited to control measures implemented by individual management centers in response to problems that are detected at interfaces.

4. SYSTEMS MANAGEMENT IMPLICATIONS OF STANDARDS

The term 'standard' can refer to any social convention (such as standards of conduct or legal standards), but it most often refers to conventions that require exact uniformity (such as standards of measurement or computer operating systems)[1]. Farrell and Saloner (1985) see standardization as a synonym for compatibility, giving compatibility between telephones and telephone networks as an example.

Standards can be divided into four general categories:

1. Formal standards
2. Dominant design (informal) standards
3. Alliance standards
4. Government enforced or regulated standards

1. **Formal standards** are created by professional "standards setting" organizations, such as AASHTO, ASTM, and ISO. Each organization has an established procedure for achieving consensus through meetings and, eventually, balloting. Members are drawn from industry and academia. These are also called voluntary standards because there is no legal requirement to follow them, though there can be strong economic incentives to adopt formal standards. Formal standards are often quite mundane, yet nevertheless important, such as the RS-232 standard governing serial ports on computers.

2. **Dominant design standards** emerge from the early stages of product competition. A period of chaos is often followed by relative stability in which the number of manufacturers and

[1] LIEBOWITZ, S. J. and MARGOLIS, STEPHEN E. (No date). The Fable Of The Keys. In *Journal of Law & Economics* 33 (April 1990). Available: http://wwwpub.utdallas.edu/~liebowit/keys1.html [1998, May 13].

designs decreases rapidly. There is very often no consensus among the various players in the market, but rather a competition to gain market dominance. Emergence of a dominant design often provides financial benefits to a particular company, such as the adoption of VHS as a standard in consumer video recorders.

3. **Alliance standards** are ad-hoc and are usually enacted by a consortium of companies, without direct involvement by a standards setting organization. These standards are different from formal standards in that committees are usually set up to define a particular standard, and are not governed by established rules; they differ from dominant design in that they depend on collaboration among competing companies. An example of alliance standards is the electronic commerce standard being developed by the RosettaNET consortium.

4. **Government enforced standards** result from regulations. Examples include passive restraint, fuel economy, and emissions regulations on vehicles. Government enforced standards usually do not force a particular solution, but instead require attainment of a performance objective. Government also plays a role in the emergence of dominant designs due to its purchasing power, especially in defense related products (military standards, in particular). These do not fall in the category of government enforced standards, as there is no mandate for private companies or individuals to follow them.

4.1 Costs and Benefits of Standardization

Standards are highly beneficial to consumers and industry because they enable the product and service development to be decentralized. Instead of a single organization designing all aspects of a system, companies can focus on areas of core competency, and rely on other organizations to create supporting products. As an example, to be competitive in personal computers, a company does not have to be competent in designing processors, memory chips, monitors, keyboards, printers, and all other system components. It can specialize in just one, and still be successful. This is only possible because the interfaces between the system components have been standardized. The existence of well defined interface standards has nurtured the rapid advancement of computer technology, much faster than the pre-PC era when integral designs were the norm.

According to Farrell and Saloner (1985) a consumer's value for a product is also larger when other consumers have compatible products (called a network externality), because this fosters development of related services and products. Examples include CDs, VHS tapes, and television, where standards have stimulated an industry of content creators and distributors. According to the oligopoly model of Katz and Shapiro (1983), customers value a product more highly when it is *compatible* with other consumers' products[2].

Perhaps the biggest dilemma in standardization is timing. Early standardization can inhibit innovation or, alternatively, fade into obscurity if alternatives become the dominant design. Especially in rapidly changing industries, waiting for a dominant design to emerge can be a more

[2] Katz, M. and Shapiro, C. (1983). Network Externalities, Competition and Compatibility. Woodrow Wilson School Discussion paper #54, Princeton University, 1983.

effective method for standardization than the lengthy process of standards setting organizations. Nevertheless, standards do not have to be the best or latest technological solution, and it is sometimes better to lock in on an inferior design (thus overcoming industry inertia) than to wait for the absolute best. Otherwise, it may never be possible to create an industry of supporting products.

A technology may be locked in for a period of time, but be replaced when a major leap forward is possible. Unless the benefits of replacing the technology are substantial, consumers are better off keeping products based on older (and inferior) technologies, avoiding the high cost of replacement and the high cost of creating support infrastructure. There also has to be a period when an enterprise stops chasing new and innovative ideas and attempts to obtain some return on investment through freezing an acceptable standard. In this period, which is akin to a plateau, new product development is not totally stopped but only incremental improvements take place in the standardized product.

In the case of government enforced or recommended standards and in the case of formal standards, companies have an added benefit in advertising conformace to the standard. Additionally, suppliers may be required to conform to a particular standard, and this may produce a higher number of orders. According to Verman (1973), standards have a greater impact when set by prominent standards setting organizations, likely for this reason. A similar theme is echoed by Lowell who, in his 1997 World Standards Day award wining paper[3], proposes adherence to international standards as a key "tool" to open new markets.

The potential drawbacks or risks in creating a standard can be described as:

- Adoption of inferior solution (some believe the QWERTY keyboard is an example)
- Fewer technology choices for consumers. This is especially important in high-tech industries where consumer needs and product characteristics need to be balanced, as opposed to "fast moving consumer goods", where the product architecture and basic form have stabilized.
- Curtailed innovation. Quinn theorizes that standards require many approvals and cause delays at every turn[4]. According to Hemenway (1975), the National Bureau of Standards refused to write interface standards for the computer industry because it feared that such standards would retard innovation[5].
- Rapid obsolescence due to leapfrogging of technologies (AMPS cellular v/s TDMA v/s CDMA).

The benefits, on the other hand, are:

- Sustained support from business enterprises since they are able to market that solution and obtain some return on investment.

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[3] Lowell, Stephen C. (1997). The Modern Day Archimedes: Using International Standards to Leverage World Markets. 1997 World Standards Day contest Winner.
[4] Quinn, James Brian (1985). Managing Innovation: Controlled Chaos In *Harvard Business Review* 63 (3) May-June 1985; 73-84.
[5] Hemenway, D. (No date). *Industrywide Voluntary Product Standards*. Cambridge: Ballinger, 1975.

- Sparks further innovation since almost all major players will have achieved the previous level of expertise.
- Cheaper products for the consumer, since a standardized product will have greater demand and economies of scale for the producer.
- Can aid innovation since it can be used as a substratum to improve and change and avoids duplication of effort.
- Gives smaller companies access to new technologies and their benefits. (e.g. EDI for small retailers.)
- Industry-wide sharing of best practices in case of process standards established by voluntary standard setting organizations where all companies benefit.

It should be recognized that whether or not formal standards are established or adopted, informal standards will emerge through dominant designs. Formal standardization has, over time, been especially useful in defining "company neutral" product interfaces. Establishing uniform connector types and configurations, for example, gives equal advantage to all companies in an industry, while raising the potential for success for the industry as a whole.

We now provide examples of alliance, formal and dominant design standards. This is followed by a discussion on the implications for intelligent transportation systems.

4.2 Examples of Standards from Outside of Transportation

The following examples are used to illustrate the standard development process and the effect of standards on industry.

4.2.1 Alliance Standards

RosettaNET is a consortium of 28 companies in software and hardware distribution, manufacture and consumption led by Ingram-MICRO. It is attempting to standardize EDI within the electronics distribution industry. All of the major retailers (Best Buy, Fry's, Circuit City, etc.) as well as the smaller ones purchase from these distributors, each of which has established Electronic Data Interchange (EDI) capabilities. Currently, the most common ordering procedure is to identify the inventory needs, check for availability with several distributors, bargain over the prices and quantities and place the order. The problems with the current methods are:

1. Retailers are required to have a separate EDI system for each distributor.
2. The smaller retailers – the so-called "*Mom and Pop's shops"* -- cannot afford one EDI, let alone ten different systems.
3. The time to complete order negotiations can be long.
4. Information on competing products and special prices does not always reach retailers.

Additionally, retailers very often do not have a sophisticated inventory control procedure and may not know order quantities and current inventories.

The broad standard proposed for Electronic Business Processes is composed of Open Content and Open Transaction Standards.

Open Content

- Standards to improve quality, depth, and consistent flow of content
- Standards to improve IT supply chain reporting and rules

Open Transaction

- Standards to improve open querying and real-time search.
- Standards to define industry-wide commodity processes.

According to Fadi Chedade of Ingram-MICRO, RosettaNet is designed "to harness the imminent, exponential growth of electronic commerce across the IT supply chain by developing, promoting, and leading the adoption of both open content and open transaction standards, along with the necessary metrics to measure the business impact of these standards on members of the supply chain."

Upon implementation, this standard is desired to produce a wide range of benefits:

1. Product specifications: All distributors will display product specifications in a standardized format that will allow for easy comparison between manufacturers.
2. The interface will be through the Internet on the individual distributor's World Wide Web page.
3. Distributors will gain knowledge of the product returns – why are the customers returning a particular product and perform statistical analysis on these figures.
4. Facilitation of Electronic Software Distribution: Since this initiative has wide acceptance as seen in the accompanying figure; there are opportunities for creating other value added services based on the electronic business standards like electronic software distribution and relationships with even smaller retailers.
5. Small retailers can now claim to have in inventory as many items as there are in the inventory of the distributor, which in the case of a company like Ingram-Micro can exceed 50,000.

4.2.2 Formal Standards

The Automotive Industry Action Group (AIAG) is an automotive trade association whose members are the North American vehicle manufacturers and suppliers, including the big three automobile manufacturers in the United States (Chrysler Motor Corp, General Motors and Ford Motor Company). These member organizations come together under the auspices of the AIAG to tackle industry issues like:

- Automatic Identification
- Construction Industry Focus Group
- Continuous Quality Improvement-CQI
- Electronic Data Interchange-EDI
- Materials Management
- Procurement & Finance

- Project Management
- Regulatory Issues
- Returnable Containers & Packaging Systems
- Telecommunications
- Truck Advisory Group
- Vehicle Product Data

They investigate the benefits of communication in new areas, examine established processes with an eye toward improvement and compare procedures to determine best practices. The result of this work is the development of new technologies and the standards that govern their usage.

The Manufacturing Assembly Pilot (MAP) project, an 18-month pilot launched in January 1994, was completed in 1996. This project attempted to demonstrate industry-wide use of electronic commerce (EC) technologies to improve communication throughout a multi-level supply chain that could save the automotive industry an estimated $1 billion per year. "The objective of the MAP effort is to improve the quality of information flowing down the supply chain and move it quickly, as quickly as a day per tier, from the OEM to the last supplier in the chain. As the suppliers at each tier in the chain begin to experience the benefits of these changes, they will improve their business practices to take advantage of the speed at which accurate and reliable information is available to them. This will in turn lead to a more agile supply chain[6]".

MAP project recommendations centered on implementing EDI and re-engineering associated business processes. This included standardization of material release data, process orders, and production plans. A standard data dictionary was developed, along with standardized message sets for data exchange. This project resulted in 58% lead time reduction, 24% improvement in inventory turns and 75% reduction in error rates, illustrating that implementing common EDI capabilities and business practices is useful for the entire automotive supply chain. The chain studied in the project consisted of 16 companies, including the automakers.

The significance of this project lies in industry-wide application and acceptance whereby the major automobile manufacturers are not only participating in the various projects but also contributing resources and benefiting from the best practices across the industry.

In the automobile industry, not all suppliers are big and hence do not have resources to reengineer their business processes to maximize profit. Projects such as MAP can help reduce costs for such measures. Additionally, many suppliers have similar business structures and processes and hence common solutions can be applied to individual cases with minimal modification.

The important issues here are compatibility and a smooth supply chain. Since this organization is composed of the big three automakers in the United States, there is considerable clout in the industry. This is different from the standardization effort in RosettaNET in that RosettaNET appears to be a one-time standard creation effort whereas AIAG is an ongoing organization with formal procedures.

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[6] http://www.aiag.org/map

4.2.3 Dominant Design Standards

Video Cassete Recorders In 1963, the very first home videotape recorder appeared in the Nieman-Marcus Christmas catalog: the Ampex Signature V costing $30,000. This product found success in the broadcast market, but was ahead of its time for consumers. Nevertheless, other companies continued development. Sony introduced its CV series half-inch, black/white open-reel format in 1965 ("CV" ostensibly stood for "consumer video"). In April 1969, Sony announced that it had developed a *magazine loaded* video tape recorder that used a one-inch tape. JVC followed soon, announcing that it had developed a machine that uses half-inch tape.

In this period, several firms were already developing the next generation products or competing formats, RCA with its *Selectavision*, CBS with its *Electronic Video Recording* and Teldec and Philips with their videodisk technologies were the frontrunners. 1972 saw the advent of Cartivision, which housed half-inch tape in a clunky cassette roughly the size of a hardcover book. The cassette employed a coaxial system wherein the two tape reels where stacked on top of each other.

In the early 1970s, several Japanese manufacturers introduced home video taping equipment. Sony clinched the first battle in the standards war by inviting JVC and Matsushita to join the new standard for cassettes using the _ inch tape, later to be called U-Matic format. The three firms agreed by December 1970 and Sony marketed its U-Matic compatible VTR in late 1971. It failed in the marketplace because of high cost and shortage of media (e.g., no pre-recorded tapes).

It was not until the mid-seventies that a true consumer oriented product came to fruition. SONY developed its Betamax format for video recording and playback as the first mass-marketed home video system, finding ways to efficiently use the space on half-inch magnetic tape. Sony invited Matsushita and JVC to license the Betamax technology in December 1974. In April 1976, the three companies agreed to have a meeting where Betamax, VHS and a third design (VX) would be compared. The JVC machine was smaller than the Betamax, but was strikingly similar in other respects. "Both were two-head, helical scanning machines using half-inch tape in a U-Matic type of cassette. Both also used azimuth recording and countered the problem of cross-talk by juggling the phase of the color signal".[7] The talks ended with JVC unconvinced that Betamax was superior to its own design.

Sony was the first in the market, selling 30,000 Betamax VCRs in 1975. However, JVC was not far behind, releasing its VHS format in 1976 in a machine that had twice the recording time of Sony's Betamax machines. Through various collaborative efforts, four other Japanese electronics manufacturers joined JVC by January 1977 and, as a response, Sony joined forces with Zenith. Matsushita, the parent of JVC attempted to persuade RCA to join the VHS camp. RCA indicated that the recording length of two hours should be increased to three or four hours and in a few weeks the JVC engineers had a prototype ready. RCA joined the VHS camp in

[7] Liebowitz, S. J. and Margolis, Stephen E. (No date). *Path Dependence, Lock-In, and History.* Available: http://wwwpub.utdallas.edu/~liebowit/paths.html [1998, April 12].

March of 1997. This continued as a pattern and VHS had an edge over the Betamax recording time throughout. VHS followed any Betamax improvements in quality closely and came out with its version not too long after. However, in the case of recording time, the VHS later had almost twice the recording time of Betamax.

Then came the inevitable *price wars* in which RCA cut prices and Sony was eventually forced to follow suit. In 1978, Sony's share was 19.1 % of the market whereas RCA had almost twice the number at 36%. By 1981 the Betamax format VCRs as a whole accounted for only 25 % of the entire market. Beta VCRs started selling for less than the comparable VHS format VCRs. In 1988, Sony admitted to plans for a VHS line of VCRs. VHS players commanded 95% of the market at that time. A year after Sony's first VHS recorders hit the market in September 1988, the Betamax share of the consumer VCR market had dropped to less than 1%.

Despite its head-start and prestige, Sony was overtaken by the late 1970s by the VHS system developed by JVC. Thus, after a period of relative chaos in terms of competing designs, the market finally had perhaps two dominant designs, one the VHS and the other, Sony's Betamax.

The major reasons for the success of VHS, however, was that Sony's one hour of playing time for Beta, geared to taping TV shows, was not sufficient for home use. VHS was first to come out with a two-hour duration, making it suitable for the prerecorded movies that are now a multibillion-dollar industry. Technologically, the two formats were perhaps equal. The law of increasing returns played a significant part in the demise of Betamax. When the number of Video titles available on Betamax format declined, the format became less popular with home users.

In this case, not having standards for tape size initially aided the consumers because it forced the competing consortia to improve and innovate in terms of the length of recording time and the quality of the picture. This also initiated interest in other technologies for recording and playing pictures and sound and led to leapfrogging of technologies. Having a standardized format when VHS became the dominant design catalyzed several ancillary industries -- videocassette manufacturers, video rental stores and pre-recorded movie cassette manufacturing came into being, benefiting the customer even more. Finally, one can say that the current status of the industry is that of maturity where no significant improvements are being made in terms of VCR performance, but are becoming obsolete with the advent of Video CD and DVD players (another example of leapfrogging).

QWERTY Keyboard The patent for the typewriter was first awarded in 1868 to Christopher Sholes, who developed the machine for several more years. One of the problems faced by Sholes was the jamming of the type bars when certain combinations of keys were struck in very close succession. As a partial solution to this problem, he arranged his keyboard so that the keys most likely to be struck in close succession approached the type point from opposite sides of the machine. This arrangement assigned the letters Q-W-E-R-T-Y in the first row of the keyboard. Since QWERTY was designed to accomplish this now obsolete mechanical requirement, maximizing speed was perhaps not an explicit objective.

E. Remington & Sons bought the rights to the Sholes patent on the typewriter in early 1873. Mechanical improvements were made to the design and commercial production commenced in late 1873. In 1888, QWERTY beat out a competing 72 key design in a typing speed competition. The winning typist later demonstrated his typing skills on the Remington machine and popularized it through his numerous public appearances. Many other designs existed at the time that might have been selected for the competition, so it might be argued that the emergence of QWERTY as the dominant design was accidental.

Professor August Dvorak patented the Dvorak Simplified Keyboard (DSK) in 1936. He claimed that it dramatically reduced the finger movement necessary for typing by balancing the load between hands and loading the stronger fingers more heavily. He claimed that this gave the DSK advantages in terms of the high speed of typing, reduced stress on typists and ease of learning. In experiments by the U.S. Navy, typing efficiency increased when the DSK was used and this added efficiency would "amortize the cost of retraining a group of typists within ten days of their subsequent full-time employment.[8]" These claims were refuted by a General Services Administration study in 1956 conducted by Earle Strong, which concluded that there were no benefits to retraining typists on the Dvorak Simplified Keyboard[9]. Another reason for this hype on the advantages of DSK over QWERTY are: Prof. Dvorak was the person who conducted these and other tests at the US Navy and thus had a stake in the DSK succeeding. Also, he held a patent for the DSK and stood to gain substantially in monetary terms if the DSK were adopted universally.

Despite the claimed advantages, the Dvorak keyboard was never accepted in the marketplace. The reasons for the success of the QWERTY can be summarized as:

1. The correlation between the supply and demand of skilled typists trained in the QWERTY keyboard arrangement.
2. The incentives offered by the manufacturers: Training programs to secretaries and clerks created its own demand, because every trainee would be of more use to a future boss if he bought Type Writers[10].
3. The fact that even competitors began to supply keyboards with the QWERTY format ensured that the new typists stressed learning the QWERTY and this increased the pool of such trained personnel.
4. QWERTY was comparable to other machines if not superior as demonstrated by its triumph in various competitions.

It has been argued thus that the design wasn't that important at all, but the marketing, the timing, the technical interrelationship and the fact that it was not possible to reverse the trend of high investment made in these machines by the businesses.

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[8] David, Paul (1985). Clio and the economics of QWERTY. In *American Economic Review*, 75, p.332-337.

[9] Liebowitz, S. J. and Margolis, Stephen E. supra note 1.

[10] Wakkerman, Johannes Cornelis Henricus, QWERTY-nomics in regional development: path dependency in industry allocation, infrastructure systems and implications for public policy. At http://home.worldonline.nl/~wakkerm/index-roth.htm

4.3 Standards Being Developed in Intelligent Transportation

Transportation standards are being created by a variety of organizations. The main purpose of standardization is to minimize the amount of incompatibility that arises when merging technologies that were created independently. Standards also allow government agencies purchasing transportation equipment to compare prices across a range of vendors. This working paper summarizes standards organizations' roles and processes in the creation of transportation standards.

Ideas for standards come from many places. The standard creating organizations may see an opportunity to standardize a new technology and draft a standard creation proposal. Industry personnel may work through their employer or professional organizations to create standards. As discussed below, each organization has a niche within the transportation field. Therefore, once a need is created, the appropriate organization can easily be identified. Formal and informal systems are used to coordinate the standard creation efforts among organizations. Informally, many active committee members participate on multiple organizations. They interact at meetings and on projects. On a formal level, the Jet Propulsion Laboratory (JPL) has cataloged the existing and emerging standards for the Federal Highway Administration (Barrett, 1996).

This document provides an overview of organizations that create transportation standards. It supplements prior work under this contract (Appendix C of Horan et al, 1997, prepared by Ron Ice), which examines the relationship between transportation standards and the National System Architecture.

4.3.1 Standards Creating Organizations in Transportation

Transportation standards are being created by many private and public organizations across a range of domains. The major efforts are listed below:

- *Roadway and Infrastructure Standards:* The American Association of State Highway and Transportation Officials (**AASHTO**) focuses on the design, construction, and maintenance of highways, and it is composed of state officials. The Institute of Transportation Engineers (**ITE**) overlaps somewhat with AASHTO. ITE facilitates the application of technology and scientific principles to research, planning, functional design, implementation, operation, policy development and management for any mode of transportation. In contrast to AASHTO, ITE is composed of academics and professionals in the transportation planning, mobility, and safety fields.

- *Electronics:* The Institute of Electrical and Electronics Engineers (**IEEE**) focuses on the theory and practice of electrical, electronics, and computer engineering, and computer science. IEEE is composed of technical professionals. The National Electrical Manufacturers Association (**NEMA**) is similar to IEEE. They focus on the generation, transmission, distribution, control, and end-use of electricity. In contrast to IEEE, NEMA represents companies that manufacture products for the electronics industry.

- *Umbrella Organizations:* Intelligent Transportation Systems - America (**ITSA**) is the only national public/private organization established to coordinate the development and deployment of ITS in the United States. They integrate information processing, communications, control, and electronics technologies to improve the overall transportation system. While ITSA integrates transportation technologies and organizations, the National Transportation Communications for ITS Protocol (**NTCIP**) provides a communications standard for all devices. This standard ensures the interoperability and interchangeability of traffic control and Intelligent Transportation devices. Finally, the US Department of Transportation's (**US DOT**) ITS Joint Program Office is also supporting and existing ITS standard processes. This organization has partnered with many other standards development organizations to reinforce existing standards. The interactivity is discussed in the following section.

- *Material Testing:* The American Society for Testing and Materials (**ASTM**) publishes standard test methods, specifications, practices, guides, classifications, and terminology. ASTM is involved in a wide range of industries, including transportation. These standards enable end-users to compare various products using an acceptable test method.

- *International Standardization:* The International Organization for Standardization (**ISO**) is a worldwide federation of national standards bodies. They compile national standards in order to create international consistency, which will promote trade and cooperation across the world.

- *Vehicle Standards:* The Society of Automotive Engineers (**SAE**) creates standards used in designing, building, maintaining, and operating vehicles on land or sea, in air or space. SAE's intelligent transportation systems (ITS) division is developing standards which improve the methods of operating vehicles.

<u>4.3.2 Relationships Among Organizations</u>

Many of the standards needs overlap many organizations and, therefore, the same agencies work together frequently. Those organizations that interact are listed below:

- *International Cooperation:* IEEE has a relationship with IEC and ISO. The IEC stands for the International Electrotechnical Commission. It's an organization of 50 countries that was created "to promote international cooperation on all questions of standardization and related matters, such as the verification of conformity to standards, in the fields of electricity, electronics and related technologies and thus promote international understanding." IEC does this by issuing publications, including international standards. IEC's scope is specifically electrotechnology. ISO and IEC do work together on information technology standards, such as computer communications, ISO and IEC have formed a Joint Technical Committee Number One, JTC1. Other areas of cooperation include the environment, safety, and electromagnetic radiation.

- *Multiple Organization Steering Committee:* In 1996, the National Electrical Manufacturers Association (NEMA) teamed with the Institute of Transportation Engineers (ITE) and the American Association of State Highway and Transportation Officials (AASHTO) under a

Federal Highway Administration (FHWA) contract to obtain more direct user input in the standards development process. The NTCIP Steering Group has been reorganized as the NTCIP Joint Standards Committee, an official Steering Committee of the FHWA-funded project. The Steering Committee includes members from the various standards organizations and industry personnel.

- *Reinforcing existing standards:* US DOT has chosen to support, guide, and reinforce the existing consensus standards efforts in the US by providing funding to five existing Standards Development Organizations (SDOs). This "bottoms-up" approach will allow US DOT to leverage significant volunteer resources and to foster public-private partnerships in the deployment of ITS. The five SDOs chosen for funding are: SAE, ASTM, IEEE, AASHTO, ITE. By utilizing the talents of all 5 SDOs, the US DOT program builds on expertise from the multiple disciplines of ITS. The US DOT program provides an important aspect of coordination and overall planning. Many of the standards identified for US DOT funding are being developed by several of the SDOs. The US DOT program is encouraging and facilitating increased coordination in US national standards efforts for ITS. The US DOT has also considered input from ITS America in choosing the most appropriate standards for near term funding. The overall goal of the program is to accelerate ITS deployment and promote national interoperability through robust non-proprietary, consensus-based national standards.

4.4 Implications of Standards for Systems Management

In earlier research under the California System Architecture project (Horan et al, 1997), interviews were completed with Caltrans Traffic Operations groups around the state, to assess their involvement in the standardization process and their steps toward implementation of the NSA.

Most interviewees were familiar with standards setting activities in NTCIP, but not in other bodies, such as SAE. Some interviewees identified people within their organization who had participated in NTCIP meetings or committees. Some stated that Caltrans headquarters was representing their district, and some felt that the electrical engineers (not operations) were representing their district. Most people were aware that NTCIP is developing communication protocols for field elements, such as signal control, ramp meter control, CMS, and CATV, and all of these felt it was an important activity. A few people were critical of the pace of progress and of commercial interests, and the high overhead imposed on communication in evolving standards.

Smaller districts and agencies appeared to be the most interested in standardization. These apparently have major problems with system compatibility and maintenance, and lack the internal resources to resolve these problems. Larger districts were also interested in NTCIP, but less so, apparently because they had the resources to resolve problems internally.

Interviews were also conducted with companies that manufacture traffic management products to assess their participation in NSA and standards setting. Four categories of products were investigated: closed-circuit-television (CCTV) cameras, loop detectors, changeable message signs, and traffic controllers. These represent the principal field elements currently being installed on California highways. Product managers at a total of 10 different companies were interviewed by telephone. Questions centered on the role of standards and system architecture in product development, as well as their input into these processes.

CCTV Kodak, Cohu, and Odetics manufacture CCTV cameras that are mounted over highways and other heavily traveled roads to monitor traffic conditions. These companies have had minimal involvement with NSA and NTCIP. Camera protocol standards are well established, so they focus their resources on developing and enhancing their cameras' features.

Kodak and Cohu deal primarily through a system integrator, who works with the government at a global level to develop traffic management plans. The system integrators define the government's technological requirements, and then interface with Kodak and Cohu to purchase cameras that fulfill the design's needs. In contrast to Kodak and Cohu, Odetics manufactures cameras for a variety of industrial applications, ranging from traffic management to security systems. They rely on their distributors to stay abreast of the government initiatives. For example, Intersection Development Corporation, an Odetics distributor, is a member of the NTCIP steering committee.

None of the three camera manufactures were concerned with meeting state specifications. They do not work with their competitors to establish industry standards because California has already defined detailed camera specifications. Furthermore, they do not have direct contact with the government agencies. Instead, they focus on system integrators as a middleman to the government.

These companies compete on factors other than defining protocols, such as the amount of light needed to view a picture, resolution, or camera lifetime when exposed to weather. They are not concerned with setting protocol standards and are not involved with the government initiatives. They do not believe that a competitive advantage can be gained by assisting in standard development.

Loop Detectors Peek Traffic and Timemark Traffic Controllers manufacture loop detectors which measure traffic flow over fixed points in the road. Both companies are working to define standards for the industry. Peek is also working with NEMA (National Electrical Manufacturers Association) and Timemark with ASTM (the Association for Standards and Test Methods) to create specifications for loop detectors. These two groups are attempting to enhance the current standards at a more detailed level.

Peek is concerned that inferior manufacturers will win business with low-quality products at discounted prices. These companies will create a perception in the marketplace that all loop detectors are poor quality products, and that governments should select an alternative technology to measure traffic flow. Therefore, Peek is working through NEMA in the belief that it will be more difficult for low-quality products to meet stricter standards, which would ultimately enhance the industry's reputation.

Both companies have worked directly with government agencies. Their motivation has been to establish relationships with the agencies, rather than pushing for certain specifications. They feel that it is their role to assist the government in establishing standards, and it is a company's option to offer additional product features which exceed specifications. Additionally, both companies are well positioned for future contracts based on their government interaction.

Changeable Message Signs American Electronic Signs, Cohu, and Vultron manufacture electronic, changeable message signs, which enable traffic management agencies to display information to drivers as they travel. These three companies have been involved with NTCIP to various degrees. Each company expressed concern regarding low quality, "fly by night" companies who tarnish the industry's reputation.

Vultron is on the NTCIP committee, and they are working to develop an industry standard protocol for changeable message signs. American Electronic Signs is on the NEMA technical committee to define protocols for all signs. Finally, Cohu is working indirectly through contacts on the NTCIP steering committee to learn the specifications early, but they will not contribute to defining them. Through their standard setting work, these companies are requiring all competitors to meet the state's specifications, thus eliminating inferior products. None of these companies are involved in industry groups other than the government programs.

Cohu and Vultron work primarily through systems integrators (similar to the camera manufacturers). The integrators help the government develop detailed protocols and overall traffic plans, and then engage the message sign companies to supply products.

Traffic Controllers Dynatrol, Intersection Development, and Safetran Traffic manufacture hardware which enable traffic management centers to make changes in field equipment from a central location. For example, the 170 controller can be used to control the timing of traffic signals or collect pollution data from a central point. These companies have diverse viewpoints on the standards setting projects. Each company currently manufactures the 170 controller, and they are anticipating California's roll-out of the 2070 controller's specifications.

Intersection Development has taken a leadership role in setting the 2070 controller's standards. Their chief engineer is an NTCIP committee head, and they are also working on a subcommittee to define protocol standards. Dynatrol has taken the opposite position. They avoid interaction with the government standards setting groups. Dynatrol's strategy is to gain acceptance on the State of California's approved products list as a low cost producer once the protocol has been established. Safetran's stance is in the middle. They gain insight on upcoming trends through their involvement with the TRB (Transportation Research Board). They are also heavily involved in defining product specifications on an informal basis. Through their relationship with the state, they are one of many companies who offer input into the products during their development stages.

None of the traffic controller manufacturing companies interact with competitors. All three are confident that the state's detailed traffic controller specifications force all competitors to produce high quality goods.

Through their standards setting involvement, each of the three companies has developed different relationships with the government over time. Intersection Development works directly with the government and system integrators. They hold local information seminars and even had a demonstration trailer tour the country for two years. Conversely, Dynatrol has virtually no interaction with government standards setting agencies. They focus on providing products that meet existing specifications. Safetran has strong working relationships with the government. The government bounces ideas off their technical staff, and they provide informal input on issues such as technical feasibility of products. They are one of many companies who have this type of relationship with the government.

4.5 Recommendations for Systems Management

ITS standards are primarily concerned with the exchange of information through defined interfaces. Standards are being developed for information exchange between TMCs and field devices, from TMC to TMC, to and from vehicles, and so on. Standards are a way to convert the ideals and concepts expressed in the NSA into tangible results, in terms of simplified procurement, "plug and play" hardware compatibility, and software compatibility. Standards are primarily directed at simplifying the process of implementing new technology and upgrading old technology.

Standardization says very little about the content of the information that is communicated or the management strategies that this communication enables. Though standardization may help create new communication channels, the mere existence of these channels will not guarantee improved systems management. This will depend on strategies to convert information into actions, such as dynamic signal control, incident response and route diversion.

Table 6 summarizes the impacts of standards developments on six areas of transportation:

Surveillance: Principally collection of real-time information from field devices, including cameras, loops, and vehicle location systems.

Information Dissemination: Communication of transportation information to travelers

Control: Control of the transportation system, through signals and vehicle control

Toll Collection: Automatic collection of user fees.

Communication: General purpose communication to support a variety of ITS services.

Management: Higher level management functions, such as incident management.

As the table shows, relatively few of the standards efforts directly impact management, though quite a few are directed at control. Nevertheless, there is value in developing standardized management processes, as in military standards for systems engineering or ISO standards for quality. And whereas standardization of system interfaces is clearly not appropriate for a single state, standardized processes for executing ITS projects could be appropriate at a state level. We believe that this is best applied in standardizing inter-jurisdictional agreements, as suggested in Section 3.

Table 6. Impact Areas of Standards

Organization	Standard	IMPACT AREAS					
		Surveillance	Info Dissem	Control	Toll Collect	Communication	Management
AASHTO	NTCP dynamic message signs		X				
AASHTO	NTCP highway advisory radio		X				
AASHTO	NTCP environment sensor stations & TWIS	X					
AASHTO	NTCP video camera control	X					
AASHTO	NTCP TMC to TMC						X
AASHTO	NTCP ramp meters			X			
AASHTO	NTCP weigh in motion	X					
AASHTO	NTCP video detection devices	X					
AASHTO	NTCP vehicle classification devices	X					
AASHTO	NTCP automatic vehicle identification	X					
ASTM	DSR 2-way, roadside, physical	X	X			X	
ASTM	DSR 2-way, roadside, data link	X	X			X	
ASTM	DSR 2-way, roadside, roadside comm equip	X	X			X	
ASTM	WIM with user requirements and test method	X					
IEEE	MW design, procure, constr, maint, and ops					X	
IEEE	Fiber optic installation practices					X	
IEEE	Standard for ITS data dictionaries					X	
IEEE	Message set template for ITS					X	
IEEE	Message sets for vehicle/roadside (ETC & CVO)				X	X	
IEEE	Message sets for incident management (EMS - TMC, E911)					X	X
ISO	Glossary of terminologies for TICS sector					X	
ISO	Reference model architecture(s) for the TICS sector					X	
ISO	Reference model architecture for generic AVI/AEI	X				X	
ISO	Stationary dissemination for traffic and travel information		X				
ISO	Automatic fee collection DSR communications					X	
ISO	Test procedures for automated fee collection				X		
ISO	Automatic fee collection requirements for DSR				X		
ISO	Locally-determined route guidance		X				
ISO	Forward obstacle warning systems			X			
ISO	Short range warning systems for low speed maneuvering			X			
ISO	Side obstacle warning systems			X			
ITE	ATC cabinet functional description			X			
ITE	ATC cabinet specification document			X			
ITE	ATA 2070 - ATC controller specification document			X			
ITE	ATC API functional description			X			
ITE	TCIP - transit data dictionary					X	
ITE/ITSA	ETTM user reqs for future national interoperability				X	X	
ITE	TCIP - transit vehicle to TMC message set					X	
ITE	TCIP - remote traveler support message set		X			X	
ITE	Traffic management data dictionary			X			
ITE	ATC cabinet standard			X			
ITE	ATC API specification			X			
ITE	External TMC - first, second, and third MS increments						X
NEMA	NTCP object definitions for actuated traffic signal controllers			X			
NEMA	NTCP object set for ramp meters			X			
NEMA	NCTP object set for vehicle classification devices	X					
NEMA	NTCP object set for video detection devices	X					
NEMA	NTCP object definitions for variable message signs		X				
SAE	ITS data bus reference architecture model					X	
SAE	Navigation/route guidance function access while driving		X				
SAE	Location reference message specification	X					
SAE	ATIS data dictionary standard		X				
SAE	ATIS traveler information service message list		X				
SAE	On-board land vehicle mayday reporting interface	X					
SAE	ATIS message sets delivered over high speed FM subcarrier		X				
SAE	In-vehicle navigation and ATIS device message set		X				
SAE	ITS data bus protocol					X	
SAE	ITS data bus gateway reference design practice					X	

5. REFERENCES

Barrett, R. (1996). "Standards and Protocols Catalog, Special Studies Standards Task," JPL D-12066 Revision D, Prepared for the Federal Highway Administration.

Chedade, Fadi in conversation with Viral Thakker.

Cremer, M. (1989). A multi-level hierarchical architecture for the freeway of the future," Proceedings of the 2nd PROMETHEUS workshop, pp. 696-704, Stockholm.

Cremer, M. (1990). Requirements from PROMETHEUS Functions for in vehicle Architecture, Proceedings of the 4th PROMETHEUS workshop, pp. 342-351, Compiegne, France.

Cremer, M. (1991). An integrated architecture for future freeway information and control systems, Proceedings of the Engineering Foundation Conference on Traffic Management Issues and Techniques, Palm Coast, Florida.

David, Paul (1985). Clio and the economics of QWERTY. In *American Economic Review*, 75; 332-337.

El Sawy, Omar in conversation with Viral Thakker.

Farrell, Joseph and Saloner, Garth (No date). Standardization, compatibility and Innovation. In *Rand Journal of Economics* 16(1) Spring 1985; 70-83.

Federal Highway Administration (FHWA, 1994), *The Intelligent Vehicle Highway System (IVHS) Architecture Program*, Washington, D.C.

Gomes, Lee (1998). QWERTY spells a Saga. In *Wall Street Journal* 02/25/1998.

Gosain, Sanjay (1997). Skanska AB: IT Strategy for Coordinating Plug and Play Supply Chains. University of Southern California, Marshall School of Business case study.

Gosain, Sanjay in conversation with Viral Thakker.

Hall, R.W. (1995) The architecture of transportation systems, *Transportation Research C*, V. 3, pp. 129-142.

Hall, R.W., M. Miller and A. Khattak (1996) Evaluating the effectivenesss of integrated traffic corridors: concept and practice. *ITS Journal*, V. 3, pp. 49-67.

Hemenway, D. (No date). *Industrywide Voluntary Product Standards*. Cambridge: Ballinger, 1975.

Horan, T., L.J. Glazer, K.S. Massey, A.Lohmann, R..Hall, C. Intihar and R. Ice (1997). California Systems Architecture Study -- Part I, Claremont Graduate School Technical Memorandum.

http://www.aiag.org/map

Katz, M. and Shapiro, C. (1983). Network Externalities, Competition and Compatibility. Woodrow Wilson School Discussion paper #54, Princeton University, 1983.

Liebowitz, S. J. and Margolis, Stephen E. (No date). Path Dependence, Lock-In, and History. Available: *http://wwwpub.utdallas.edu/~liebowit/paths.html* [1998, April 12].

Liebowitz, S. J. and Margolis, Stephen E. (No date). The Fable Of The Keys. In *Journal of Law & Economics* 33 (April 1990). http://wwwpub.utdallas.edu/~liebowit/keys1.html [1998, May 13].

Los Angeles, City of (no date). Automatic Aid/Initial Action Agreement for Exchange of Fire Protection and Rescue Services"

Lowell, Stephen C. (1997). The Modern Day Archimedes: Using International Standards to Leverage World Markets. 1997 World Standards Day contest Winner.

Malhotra, Arvind in conversation with Viral Thakker.
Michon, J.A. (1985) A critical view of driver behavior models: What do we know, what should we do? in L.Evans and R.C. Schwing (Eds.) *Human behavior and traffic safety*. Plenum Press, New York.
Quinn, James Brian (1985). Managing Innovation: Controlled Chaos. In *Harvard Business Review* 63 (3) May-June 1985; 73-84.
Rosenbloom, Richard S. and Cusumano, Michael A. (no date). Technological Pioneering and Competitive Advantage: The Birth of the VCR Industry. In *California Management Review* 29 (4) Summer 1987; 51-76.
U.S. Department of Transportation (1996a), Joint Architecture Team, Loral Federal Systems, Rockwell International, *ITS Architecture Implementation Strategy.*
U.S. Department of Transportation (1996b), Joint Architecture Team, Loral Federal Systems, Rockwell International, *ITS Architecture Physical Architecture.*
U.S. Department of Transportation (1998) US DOT's Conceptual Approach for Ensuring Consistency with the National ITS Architecture (February 24, 1998), www.its.dot.gov/archconsis/consist.htm.
Varaiya P. (1991) Smart cars on smart roads: Problems of control. PATH Technical Memorandum 91-5, University of California, Berkeley, CA.
Varaiya P. and Shladover S.E. (1991) Sketch of an IVHS systems architecture, PATH Research Report, 91-3, University of California, Berkeley, CA.
Verman, Lal Chand (1973). Standardization, a new discipline, with a foreword by Francis L. LaQue. Archon Books, Hamden, Conn.
Wakkerman, Johannes Cornelis Henricus, QWERTY-nomics in regional development: path dependency in industry allocation, infrastructure systems and implications for public policy. At http://home.worldonline.nl/~wakkerm/index-roth.htm.
Wallace, Richard in conversation with Viral Thakker.