U.S. Department of Transportation

Developing

Freeway and Incident Management Systems

Using the National ITS Architecture

U. S. Department of Transportation

Intelligent Transportation Systems Joint Program Office

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16. Abstract

This is one of a series of documents providing support for deploying Intelligent Transportation Systems (ITS). This series addresses Traffic Signal Control Systems, Freeway and Incident Management Systems , Transit Management Systems, and Traveler Information Systems. The National ITS Architecture provides a common structure for deploying these systems. An important point of these documents is that you can reap operational benefits while saving staff hours and design costs by using the National ITS Architecture as a deployment guide.

This document focuses on freeway and incident management systems, a component of ITS. It aims to provide practical help for the transportation community with deploying freeway and incident management systems in an integrated, multimodal environment using the National ITS Architecture. ITS is the application of management strategies and technologies to increase the efficiency and safety of national, regional, and local surface transportation systems.

This document covers the basics of freeway and incident management ITS applications, the role the National ITS Architecture can play in freeway and incident management system project development, the development process for a regional architecture, some challenges faced by transportation management agencies, and some best practices and lessons learned for developing and deploying advanced freeway and incident management systems. The regional architecture will indicate how current and future systems in the region may be integrated to obtain the added benefits available through integration of these systems.

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1. Introduction and Summary

1.1 Purpose and Intended Audience

This is one of a series of documents providing support for deploying Intelligent Transportation Systems (ITS). This series addresses:

- Freeway and Incident Management Systems
- Traffic Signal Control Systems
- Transit Management Systems
- Traveler Information Systems

The National ITS Architecture provides a common structure for deploying these systems. An important point of these documents is that you can reap operational benefits while saving staff hours and design costs by using the National ITS Architecture as a deployment guide.

1.1.1 Intended Purpose

This document focuses on freeway management and incident management systems, which are highly related components of ITS. It aims to provide practical help for the transportation community with deploying these systems in an integrated, multimodal environment using the National ITS Architecture. ITS is the application of management strategies and technologies to increase the efficiency and safety of national, regional, and local surface transportation systems. Intelligent Transportation Systems form the basis for a new way of doing business in addressing the nation's surface transportation needs. Rather than solving transportation challenges solely by building additional roadway capacity, ITS strategies strive to use existing facilities more efficiently by applying technology and effective management strategies to collect, transfer, process, and share historic and real-time transportation information. This includes the use of computer, communications, sensor, information, and control technologies and a structured approach to manage the planning, development, deployment, operations, and maintenance of ITS systems and projects.

This document is designed as a guide for how the National ITS Architecture can be used in the process of designing, developing, and implementing effective freeway and incident management systems. Development of the National ITS Architecture arose out of a need to provide a common framework for deployment of ITS across the nation. The National ITS Architecture contains the information you need to develop a regional architecture, to be assured you haven't overlooked anything important, and to ensure you are preparing an efficient deployment. This document shows how to enhance existing and emerging freeway and incident management systems, facilitate design and upgrade of future systems, and help overcome challenges commonly faced by freeway and incident management personnel. It does not describe freeway management or incident management fundamentals, since that background already exists in other technical assistance documents, such as the Freeway Management Handbook [FHWA, August 1997] and the Freeway Incident Management Handbook [FHWA, July 1991 with an updated version expected in Fall 1998]. This document provides a basic overview of freeway and incident management systems and covers the role the National ITS Architecture can play in project development, the development process for a regional architecture, some challenges faced by traffic management agencies, and some best practices and lessons learned for developing and deploying freeway and incident management systems. The regional architecture will indicate how current and future systems in the region may be integrated to obtain the added benefits available through integration of these systems.

Freeway management can be defined as the control, guidance, and warning of traffic in order to improve the flow of people and goods on limited access facilities. A freeway management system, then consists of the infrastructure components utilized to accomplish the goals and objectives which may be established by a region or agency for that particular system. The components of this system include the field hardware (cameras, variable message signs, electronic toll tag readers, etc.), communications equipment (including connections to other systems or agencies),traffic management system (computer hardware and software), and the people who staff this center. These components allow the freeway management system to combine personnel, operational strategies and technologies together to control and manage traffic more efficiently.

Incident management is a coordinated and planned approach for responding to incidents when they occur on either freeways or arterial surface streets. This involves the systematic use of human and mechanical processes for detecting, responding to, and clearing incidents. Incident management is a cooperative, multi-agency approach to address nonrecurrent congestion problems on freeways typically caused by incidents. Incident management is an operational strategy of the freeway management system involving the coordinated and planned approach to restore traffic to its normal operation as quickly as possible after an incident has occurred.

Because of the natural relationship between freeway and incident management functions, this document covers both, providing a variety of examples that apply to one or both of these systems throughout the main sections. In many areas, the state DOT has the primary responsibility for these functions on the freeway system. However, it is recognized that incident management programs and systems often provide coverage and response on arterial streets. Because of the number of additional agencies and stakeholders that are involved with the overall incident management function (including law enforcement, fire and rescue, emergency medical services, towing, and other transportation agencies), it is also recognized that institutional cooperation is paramount to effective incident management. In any case, the concepts discussed throughout the document can be similarly applied to a wide range of freeway or incident management systems.

1.1.2 What is the National ITS Architecture?

The National ITS Architecture defines the components of the surface transportation system, how they interact and work together, and what information they exchange to provide 30 ITS user services. These 30 user services have been identified by the U.S. ITS community as part of the National ITS Program to guide the development of ITS and are listed in Section 2. A key requirement for development of the National ITS Architecture [FHWA, January 1997] was that it include the transportation functions necessary to provide the 30 user services.

Using the National ITS Architecture will save implementers time and money because it contains much of the up front analysis and planning information necessary to deploy ITS, including project definition and requirements, information exchange requirements, system evaluation criteria, cost development information, communications analysis, and benefits of deployment of specific ITS applications.

1.1.3 Intended Audience

The intended audience of this document includes:

- Transportation engineers, planners, and mid-level administrators for state, local, and regional transportation agencies, including metropolitan planning organizations and regional transportation authorities, involved in planning, designing, implementing, operating and maintaining freeway or incident management systems.
- Transportation professionals and others interested in understanding freeway and incident management systems challenges and solutions based on the Architecture.

The audience is assumed to be reasonably knowledgeable in traffic management operations and maintenance and to have had some practical experience in this field. More specifically, if your work involves planning, designing, implementing, operating or maintaining freeway or incident management systems, and you perform one of the following functions within your organization, this document is intended for you:

Regional Transportation Planning	Project Implementation
Traffic Engineering	ITS Project Definition
Identification and Allocation of Project Funds	Preliminary and Final Design

Procurement of Services and Equipment	Project Acceptance Testing
Project Approval	System Evaluation
Project Management	Operations, Maintenance
Training	

1.2 Freeway and Incident Management Systems

The 1983 FHWA Freeway Management Handbook characterized freeway management as the control, guidance and warning of traffic to improve the flow of people and goods on freeway facilities [FHWA, 1983]. This description of freeway management remains accurate; today, however, "the definition of freeway management should be expanded to encompass all activities undertaken to operate a freeway facility in a manner consistent with predetermined goals and objectives… including those related to impacts on and the influence of surrounding communities and jurisdictions "[FHWA, August 1997]. In addition, the systems being used and the measures being taken today to improve the flow of people and goods on freeways are significantly different than in the past. There have been great advancements in both detection and communications systems; new technologies have been applied and operating practices have been modified as operating agencies have gained experience in managing freeway traffic. As travel patterns changed, the regional framework designed to foster cooperation among transportation agencies has become increasingly important. Furthermore, freeway management strategies have become multi-modal. These factors have contributed to the more dynamic and user oriented nature of freeway management systems.

In general, each freeway management system is designed to meet the specific social and political objectives of each community. Fundamentally, however, freeway management systems strive to achieve the following:

- To accurately monitor freeway performance and make appropriate traffic control decisions in a timely manner
- To reduce the impacts and frequency of recurring congestion on freeways
- To minimize the duration and severity of non-recurring congestion on freeways
- To maximize freeway efficiency and public safety
- To provide freeway users with appropriate information to enable route and mode selection

1.2.1 Freeway and Incident Management Functions

To achieve the objectives stated above, freeway management systems must be able to effectively perform some or all of the following functions (Figure 1.2-1):

- Surveillance and Incident Detection
- Ramp Control
- Information Dissemination
- Incident Management
- Lane Use Control

Ë Coordination with Other Traffic and Freeway Management Systems and Incident Detection

1.2.1.1 Surveillance

The cornerstone of effective freeway management is an overall surveillance and incident detection system, for it is through the use of that system that the freeway operator gets an answer to the fundamental question "What are the current operating conditions on the freeway?" The answer to that question can be derived and confirmed from a number of sources in a number of ways, some using advanced technology (e.g., electronic detection systems and detection algorithms) and others using simple methods (e.g., cellular phone call-ins, and observations by Freeway Service Patrol personnel).

Typical electronic surveillance systems detect environmental conditions, volume, speed, occupancy, and traffic densities. This data is then used to determine the state of freeway operations, the location and degree of congestion, and potentially to estimate average travel-times. A number of algorithms and other techniques have been developed that are being used to detect freeway incidents. Weather conditions (atmospheric and road surface conditions) can be observed by environmental sensor stations.

The most commonly used electronic detection device in freeway management systems today is the in-pavement loop detector, also called the magnetic or inductive loop detector. Some reliability problems have been experienced in some loop detector installations, and accessibility for carrying out maintenance activities on loops located in high-volume traffic lanes have proved troublesome. This has stimulated development of other detection technologies, especially those that can be located outside of traffic lanes. These detection technologies include video (CCTV), sonic, radar, infrared, and Dedicated Short Range Communications (DSRC) based innovations.

These options may offer greater flexibility, reliability, and lower maintenance costs, but will generally result in higher initial costs and require more highly skilled personnel to provide support for such systems.

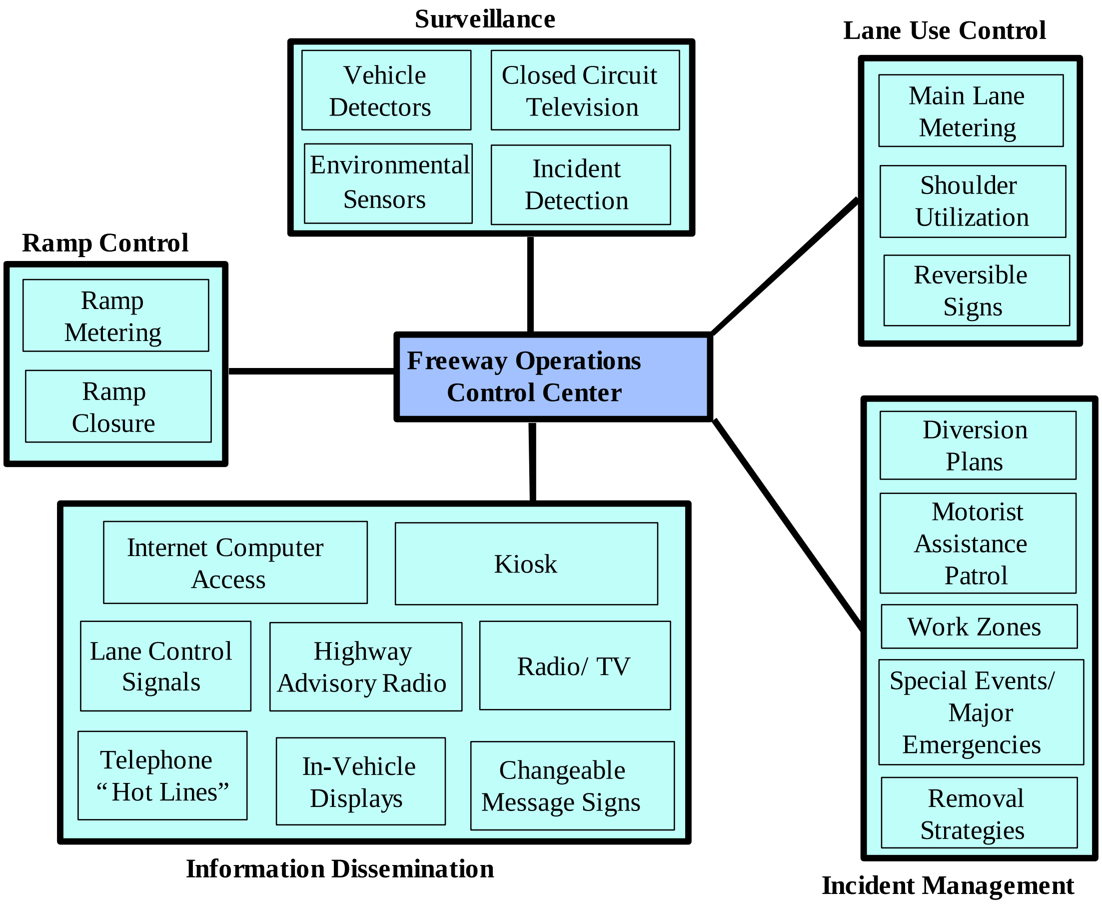


Figure 1.2-1. Freeway Management Functions

1.2.1.2 Ramp Control

Ramp metering and control can produce a significant improvement in freeway traffic flow by reducing the turbulent flow conditions and congestion that occur frequently at entrance ramps. Improvements are brought about through the control of two factors:

- Control of the volume of on-ramp traffic to the level that the freeway can accommodate without a breakdown in traffic flow on freeway through lanes. Here, the goal is to maintain the balance of the demand-capacity relationship and to avoid a breakdown of traffic flow in the downstream freeway segments. This measure is generally seen as requiring a significant diversion of on-ramp traffic to surface streets, although as discussed below, such is frequently not the case.

- Controlling the rate of arrival of on-ramp traffic into the freeway lanes. Here, the goal is to break down the constant stream of traffic that is forcing its way into the "head-of-the-line" at the freeway lanes. Without ramp metering, this produces turbulence and inefficiencies within the traffic stream and creates congestion upstream of the on-ramp. The ramp meter is used to control the number of on-ramp vehicles entering the freeway at any one time (usually one to three vehicles at a time) such that any resultant "shock waves" can be dissipated within the freeway traffic stream before the next small increment of on-ramp vehicles arrives to enter the freeway.

Experience in the operation of ramp meters has shown that in many instances, the control of the rate of arrival has been the primary contributing factor in reducing congestion and improving traffic flow on the freeway. It has frequently been observed that the system can actually serve a greater volume of on-ramp traffic under the metered operation. At the same time the operating conditions on the freeway improve. In one study, freeway speeds were shown to improve by as much as 35% while accidents declined nearly 30%. This is attributed to the fact that the turbulent flow and inefficient operations created by entering vehicles is avoided; the freeway thus operates at peak efficiency.

Consideration must be given to the storage space required for queuing vehicles in ramp metering installation design. If adequate consideration is not given to this issue, a potential exists for the end of the queue to extend back onto the surface street, creating traffic flow problems for the adjacent traffic signal control system.

Ramp meters can be operated in a variety of ways, ranging from using a fixed rate that varies with time-of-day, to a fully traffic responsive system in which the rate is automatically varied as upstream freeway volumes vary. The fully responsive operation will optimize the benefits that can be realized through the use of ramp meters.

1.2.1.3 Information Dissemination

As the state of the practice in freeway management systems has developed over several years, improvements in techniques of quickly gathering accurate information about traffic flow conditions have come about. There has been a growing appreciation of the need to disseminate this information to a host of users in a timely manner. This information must be provided to enforcement agencies and other emergency service providers so that appropriate response activities can be initiated. It should also be provided to other operating agencies whose facilities may be affected by the freeway operating conditions and to the traveling public who may be impacted by the current freeway traffic conditions. A variety of entities rely on the freeway system to conduct business. Information should be provided to them and to the media. Information dissemination is essential to allowing the users of the transportation system to make informed decisions related to modifying their travel (routes, times, mode) which in turn can help alleviate the traffic problems being experienced on the freeway.

The media can play an important role in transportation related information dissemination. The primary business of the media is to disseminate information. They have the required resources in place to quickly disseminate information to a wide variety of people. Commercial radio provides a very important avenue for getting information to the motorist in the vehicle. By and large the media has expressed great interest in receiving this information and in providing it to their customers. The media is generally interested in being a partner in solving the traffic congestion problem. The media should be included as an important stakeholder in any program aimed at the widespread dissemination of information to large numbers of people.

Information dissemination may be accomplished through field devices such as variable message signs, highway advisory radio and information beacons, or through the services of an ISP. DSRC technology coupled with in-vehicle information devices can also be used for information dissemination. DSRC is a wireless technology used to communicate between the roadside infrastructure and a device inside the vehicle. Information transfer can also be done through telephone lines, cellular phones, on-line computer services, one-way broadcasts (e.g., FM subcarrier), web sites, and television.

In the design, development and operation of a freeway management system, it is important that the need for widespread dissemination of information be recognized. An optimum blend of systems, technologies, operating procedures, partnerships and agreements should be put into place so that the information being collected is distributed quickly and in an appropriate form to the users.

1.2.1.4 Incident Management

Incident management includes activities involved in identifying, responding to, and clearing roadway incidents and emergencies. It is the coordinated use of human and technical resources to restore full freeway capacity after incidents and reduce the duration of the disruption. Incident management involves actively managing traffic flows throughout the duration of the incident, and through the period of restoration of traffic flows. It requires continual monitoring and adjustment of the traffic management plan as clearance of the incident progresses through its various phases and the provision of information to the traveling public until traffic flows are restored to normal conditions. Effective incident management encompasses six basic phases:

- Detection/Verification

- Response
- Scene Management
- Traffic Management
- Incident Clearance
- Motorist Information

In practice, these phases often are concurrent or overlapping. Even in the absence of a formal incident management program, these phases will occur to some degree. However, a formal incident management program can greatly improve the efficiency and effectiveness of these phases. Each phase of effective incident management is briefly discussed below.

Detection/Verification

Incident detection is the process that brings an incident to the attention of the agency or agencies responsible for maintaining traffic flow and safe operations on the facility. The following methods are commonly used to detect incidents:

- Roadway vehicle detectors and incident detection systems
- Cellular telephone (911 or non-emergency motorist assistance/reporting number [311])
- Video and closed circuit television
- Motorist aid call boxes
- Service patrols and law enforcement

Response

Incident response is the activation, coordination, and management of the appropriate personnel, equipment, communication links, and motorist information media as soon as there is reasonable certainty that an incident is present. An appropriate response is dependent on understanding the nature of the incident and the steps and/or resources that are necessary to return the facility to pre-incident conditions.

Scene Management

Scene management is the process of accurately assessing incidents, properly establishing priorities, notifying and coordinating with the appropriate resources, working efficiently with other responders, maintaining clear communications, and clearing incidents in a safe, timely and efficient manner. Ensuring the safety of response personnel, incident victims, and other motorists is the foremost objective of incident scene management. Requirements for effective scene management include:

- Establishing an incident command post
- Designating a scene manager or incident commander
- Including representative involvement from each involved agency
- Staging of emergency vehicles and equipment

Traffic Management

Traffic management applies traffic control measures in the area of an incident site, including:

- Lane closures and openings
- Ramp metering
- Use of alternate routes

Incident Clearance

Incident clearance is the process of removing wreckage, debris, or any other element that disrupts the normal flow of traffic from the roadway and restoring roadway capacity to its pre-incident condition.

Motorist Information

Motorist information is the activation of various means of disseminating information to motorists. Devices commonly used to disseminate motorist information include:

- Highway Advisory Radio
- Variable Message Signs
- Commercial radio broadcasts
- In-vehicle route guidance
- Commercial and cable television traffic reports
- Internet
- Commuter information telephone lines

Planning for Incident Management

In the development of an incident management program, it is crucial that roles and responsibilities be defined, particularly those of the freeway operating agency and the enforcement agency. Coordinated planning should be carried out with local agencies regarding the use of local streets as alternate routes during major incidents. Specific routes should be identified and conditions under which they will be utilized for diverting traffic should be established. Procedures to activate the alternate routes also need to be developed. Improvements needed to local routes to accommodate diverted traffic should be put into place. This cooperative, coordinated pre-planning can go a long way towards avoiding misunderstandings between agencies during the flurry of activities that must take place immediately following a major incident. Agencies must also ensure that adequate training is provided to teach their personnel proper procedures in a variety of situations.

1.2.1.5 Lane Use Control

Lane capacity is a limited resource, and in many cases is not expandable. Lane use control provides a set of activities to ensure maximum output from this resource. These activities are aimed at:

- Reducing congestion and accidents
- Improving stability of traffic flow
- Facilitating incident management
- Reducing driver's stress
- Altering the directional capacity of the freeway

These are achieved through efficient use and access of freeway lanes, temporary use of shoulders, reversible lanes, High Occupancy Vehicle (HOV) treatments, and restrictions on some vehicle classes.

1.2.1.6 Coordination with Other Traffic and Freeway Management Systems

Effective freeway management requires a regional approach. State and local agencies need to work closely with each other in developing and implementing a coordinated management plan. Experience has shown that congestion mitigation and incident management strategies can be greatly improved if regional cooperation exists. Freeway management systems planning and design must take into account and facilitate communication and coordination among agencies.

At an early stage in the development of a freeway management system, agencies need to consciously engage in a cooperative effort to plan and design the system. It is essential that the system being designed is compatible with other traffic management systems in the region. The roles and responsibilities of each agency involved in the operation of the system should be established and made part of normal operating procedures.

1.2.2 Benefits of Freeway and Incident Management Systems

Freeway management systems have demonstrated benefits over the years in several areas including travel time, speeds, capacity, and environmental impacts. Table 1.2-1 summarizes the typical range of freeway management system benefits as reported by the U.S. Department of Transportation [Mitretek, 1997].

Table 1.2-1. Summary of Freeway Management System Benefits

Travel Time	Decreased by 13% - 48%
Travel Speed	Increased by 16% - 62%
Freeway Capacity	Increased by 8% - 25%
Total Accidents	Decreased by 24% - 50%
Fuel Consumption	Decreased fuel used in congestion by 41%
Emissions (Detroit Study)	Decreased CO emissions by 122,000 tons annually Decreased HC emissions by 1400 tons annually Decreased NOx emissions by 1200 tons annually

Effective incident management systems have also produced significant benefits where they have been implemented. Typical reported benefits of effective incident management programs include:

- Improved highway safety (e.g., reduce the number of secondary incidents)
- Improved efficiency of operating agencies
- More efficient use of equipment and personnel
- Improved dissemination of motorist information
- Reduced delay
- Improved freight mobility
- Improved incident response time
- Reduced environmental impacts
- Reduced operating costs for motorists
- Improved clearance time, which results in a reduction in the time responders are needed
- Improved clearance time
- Improved safety for incident victims, response personnel, and other motorists
- Improved interagency relationships and understanding

The Institute of Transportation Engineers (ITE) has estimated 10% –45% decreases in travel time during congested times using incident management programs included in freeway management systems [Meyer, 1989]. The following are examples of benefits of incident management and emergency services in metropolitan areas that have successfully implemented and operated incident management programs:

- *Denver, Colorado, Mile High Courtesy Patrol* — A before-and-after study was conducted on a segment of I-25 to determine the effectiveness of the program. This study determined that on an annual average, courtesy patrols have reduced delay costs of traffic delays between $0.8 and $1.0 million in the morning peak period, and $0.9 million for the evening period.

- *Connecticut* — A 1990 report indicated that an incident management system involving 80 miles of roadways in the Fairfield region would produce an annual savings of 2.38 million vehicle hours of delay and reduce fuel consumption by 1.43 million gallons. The same report indicated that a system in the Hartford region would result in a saving of 1.72 million vehicle hours of delay and 1.03 million gallons in fuel savings. In addition, it was estimated that a system in the New Haven metropolitan area involving 30 miles of roadway would result in a saving of 1.23 million vehicle hours and savings of 0.73 million gallons of fuel.

- *Chicago, Illinois* — The benefit/cost ratio of Illinois DOT Minutemen freeway service patrols was calculated to be 17 to 1. An estimated 18 percent reduction in secondary incidents and 60 percent reduction in congestion are attributed to their operation.

- *Charlotte, North Carolina, Motorist Assistance Patrol* — Using an FHWA traffic simulation model to calculate the benefits of a reduction in incident related delays, a benefit/cost ratio was calculated to be 7.6 to 1.

- *Houston, Texas, Motorist Assistance Programs* — Based on traffic delay reductions that can be attributed to motorist assistance programs, benefit/cost ratios between 7 to 1 and 36 to 1 were determined, depending on the individual facility being evaluated. It is estimated that the incident management program saves the city $8.4 million annually through reduced delay.

- *Richardson, Texas* — By providing tow truck dispatchers with video feeds from closed circuit television (CCTV), the dispatcher has the ability to place equipment in the vicinity of the incident prior to police request. This reduces incident clearance times by an average of 5 to 7 minutes. In addition, it greatly improves the ability to send the proper equipment to the incident.

- *Minneapolis, Minnesota* — The Minnesota Highway Helper Program reduces the duration of vehicle stalls by an average of 8 minutes. Vehicle stalls represent 86 percent of the service calls to which the Highway Helpers respond. Annual benefits attributed to the program through reduced delay totals $3.0 million for a program that costs $620,000 to operate.

- *New York, New York* — Service patrols in the New York City metropolitan area reduced hours of vehicle delay by 7,960,000 from September 1995 through August 1996. This resulted in a benefit/cost ratio of 35.0 to 1.

- *Brooklyn, New York* — Before the implementation of an Autoscope automated incident detection system along the Gowanus Expressway, the average time to clear an incident was 1.5 hours. Since the installation of 20 CCTV cameras, the video images of incidents are now sent directly to operators who determine the severity of the conditions. The time required to detect and clear vehicle breakdowns has been reduced to 19 minutes, while the average time to clear all types of incidents has been reduced to 31 minutes (a 66% reduction).

- *Atlanta, Georgia* — In preparation for the 1996 Olympic Games, several ITS capabilities were added to assist in moving visitors and vehicles in an extremely crowed area. The regional ATMS program served to foster improved interagency coordination. The mean time between the first report of an incident and incident verification was reduced from 4.2 minutes to 1.1 minutes, a reduction of 74%. Mean time between incident verification and automated generation of incident response was reduced from 9.5 minutes to 4.7 minutes (50%). The mean time between incident verification and clearance of traffic lanes was reduced from 40.5 minutes to 24.9 minutes (38%). The maximum time between incident verification and clearance of traffic lanes was reduced from 6 hours 15 minutes to 1 hour 28 minutes, a 60% reduction.

- *Maryland (Chesapeake Highway Advisories Routing Traffic) CHART* — A benefit/cost ratio of over 7 to 1 was calculated for the CHART incident response program. Cost savings were a result of reduction in delay, fuel consumption, and secondary incidents.

Other unquantifiable benefits may also be derived from effective incident management systems:

- Reduced frustration and inconvenience to the individual motorist involved in an incident.
- Improved safety and reduction in collision potential by removing vehicles from the roadway and shoulder quicker
- Improved public safety due to improved emergency response
- Reduced noxious fume emissions and improved air quality due to reduction in delay
- Enhanced inter-jurisdictional relationships
- Improved public relations

1.2.3 Integration Challenges and Needs

While freeway and incident management systems provide many important benefits, the benefits can be increased by using the National ITS Architecture to guide integration with other parts of the transportation system. The National ITS Architecture promotes integration among the various transportation subsystems, meaning that they are interconnected with each other by communications links and are therefore able to exchange information with one another. The various subsystems exchange information to coordinate their operation within a region and to provide transportation functions to each other. An important aspect of this sharing is that operations in each center may be improved by smoothing the transitions between agencies and jurisdictions.

Regional Coordination

The need for sound coordination between freeway operating agencies and other agencies involved in incident response is well known. Increasingly, though, agencies involved in freeway and incident management are being faced with additional challenges related to integration and coordination with other local transportation operating agencies. For example, integration of freeway management systems with traffic signal control systems is illustrated in Figure 1.2-2.

Traditionally, freeway management systems have been designed to optimize traffic flow on the freeway network, often without considering the impact on arterials or other transportation systems. The advent of advanced computer, communication, surveillance, and traffic signal controller technology, however, has made it possible to integrate transportation systems operated by different agencies (e.g., local signal systems).

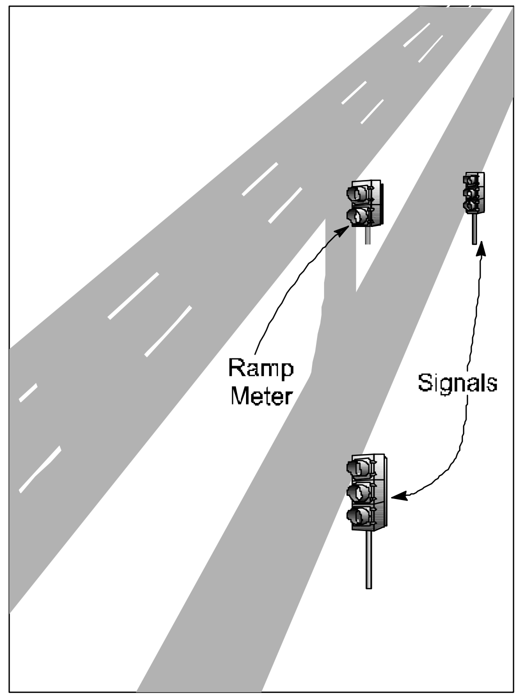


Figure 1.2-2. Regional Coordination

One example of this coordination is the adjustment of signal timing in the vicinity of an incident. This can help to clear traffic nearby and decrease the flow of vehicles entering the area before surface street congestion from the incident is compounded. Another example is the adjustment of ramp metering rates for entrance ramps to a freeway if there is an incident along the service road or adjacent surface streets in order to better balance the traffic flow. These examples illustrate the coordination of a traffic signal control system with freeway and incident management systems.

Having shared and agreed upon concepts for the operational and coordination requirements between the freeway management and the local traffic signal control system, both during and in the absence of incidents, can go a long way towards establishing cooperation between agencies. It can also serve to minimize misunderstandings regarding issues such as the installation and operation of ramp meters and the use of local streets as alternate routes for freeway traffic during incidents.

Traveler Information Systems

As discussed in Section 1.2.1.1, agencies responsible for freeway and incident management activities are by necessity in the business of monitoring the operational status of the freeways and intersecting ramps. The information on traffic conditions that is collected during the surveillance function can obviously be used to support the dissemination of traveler information through a variety of methods. The end providers of traveler information to users include the public sector agencies themselves as well as a variety of commercial organizations such as the media and information service providers. Given the importance of the freeway system in most transportation networks, organizations attempting to create a regional, multimodal traveler information service will likely want access to the information that is gathered by freeway operating agencies. In addition, the media, other agencies, and traveler information service providers may want to have the ability to view video feeds from freeway CCTV installations.

Electronic Toll Collection Systems

Electronic toll tags and other DSRC technologies are providing additional options for freeway managers to consider for operating policies and traffic monitoring. Some freeways are operated as toll facilities and are already benefiting from the efficiencies provided by electronic toll collection systems. Other freeways are operated with High Occupancy Vehicles (HOV) restrictions (at least during peak periods), and some areas have (or are planning to) experimented with High Occupancy Toll (HOT) operations, in which spare capacity on HOV facilities is "purchased" by single drivers. Electronic toll tags can be effectively used to manage and monitor facilities used in these situations and could be used to enable alternative transportation pricing methods in the future. Regardless of the operating policies being followed, electronic toll tags and other DSRC technologies that are installed in vehicles using the freeway facility can serve as sources of probe data (travel time reports between readers). Freeway managers can take advantage of this additional source of information by using it to identify potential problems, adjust operations plans accordingly, and provide information to travelers (directly and/or indirectly by passing it along to traveler information service providers).

Incident Management and Institutional Coordination

As stated earlier, there is a strong need for coordination between all of the agencies involved in or affected by the various phases of incident management activities. All of the involved agencies (including freeway management agencies, law enforcement, fire and rescue, emergency medical services, towing, traveler information providers, and other transportation agencies) should understand each other's roles and responsibilities in any given situation. In addition, technical compatibility is needed so that the utilized communications frequencies of the various agencies can be shared by the other agencies. The ability to implement cooperative diversion plans or otherwise adjust traffic operations also requires a degree of data sharing and control integration that will be facilitated by ITS.

Integrating the systems of various agencies allows information from one to be passed to another, rather than using multiple sensors or systems to accomplish the same task. This integration allows individual components of ITS to work together and will pay great dividends to transportation customers and resultant cost savings to agencies. Institutional benefits are also to be expected with the integration of transportation systems. Better, more complete information allows the job of managing transportation to be done better. Every agency has a piece of the picture—by sharing this information through integrated systems, everyone sees the same, whole picture. The exchange of information between agencies requires the keepers of the information or stakeholders to be involved from the initial planning of these systems to address transportation operations and management issues. The integration of systems across institutional and modal boundaries fosters team building while allowing all participants to make good use of scarce resources.

1.3 The National ITS Architecture Can Help You

1.3.1 Help for Traffic Managers

Similar to a model home blueprint, the National ITS Architecture provides a common structure for the design and implementation of ITS. The National ITS Architecture defines the functions (e.g., gather traffic information) that must be performed by components or subsystems, where these functions reside (i.e., roadside, traffic management subsystem, in-vehicle, etc.), the interfaces and information flows between subsystems, and the communications requirements for the information flows (e.g., wireline or wireless). Just as the model home design is often changed to meet the needs and living space requirements of individual families, the common structure provided by the National ITS Architecture can be tailored to meet a region's unique transportation needs.

In addition, the National ITS Architecture identifies and specifies requirements for standards needed to support national and regional interoperability, as well as product standards needed to support economy of scale considerations in deployment. These standards will include the formal definition of the physical interfaces and information exchange requirements of the National ITS Architecture.

A lot of time and effort went into developing the National ITS Architecture—for a very good reason —to make the process of designing and implementing these systems easier for you.

YOU CAN SAVE STAFF HOURS AND ENGINEERING DESIGN COSTS BY USING IT.

An agency using the National ITS Architecture can save time and money in the development of a project from its inception through its implementation. Some capabilities of the National ITS

Architecture that are particularly important to effective freeway and incident management system development are listed below.

- Correlates services and requirements to subsystems and data flows, thus providing traceability for a project to the selected architecture.
- Illustrates the benefits that can be obtained through efficient grouping of ITS functions plus sharing of information for multiple purposes across the transportation system, avoiding redundancy and saving money.
- Provides a view into the future to identify services and functionality that may not have been initially considered, currently needed, or even feasible. This provides a checklist of future capabilities that could be planned for now in anticipation of future needs. Planning for these future needs in database and interface designs will save substantial costs of modifications needed for these later additions.
- Provides an extensive list of the transportation agencies (by matching the functions they perform with the corresponding subsystem names in the National ITS Architecture) that your agency should consider talking to during initial planning of an implementation (i.e., the stakeholders).
- Defines the kind of information one should consider sharing among these agencies. Your agency can use this information as a checklist in planning the project and in discussions with other stakeholders to show how they can participate through sharing of the information.
- Serves as a good starting point or template (which can be tailored) for developing the regional architecture that will drive the designs for specific projects. Starting with the National ITS Architecture, one can merely delete the functions and information flows that do not apply and then incorporate any specific local requirements and considerations. This is more fully addressed in Section 3.

- Provides a departure point for developing functional requirements and system specifications to be included in a procurement package, including identification of the interfaces (some of which may have approved standards or standards work under way) and data exchanges that must be included.
- Provides ballpark estimates of costs for a wide range of ITS-related equipment and services that can be used for initial project costing.
- Can support a check on the product being provided by a design contractor (if the contractor is asked to demonstrate the use of the National ITS Architecture and its relationship to the design being offered).

For many of the reasons stated above, the National ITS Architecture can serve as a good starting point for developing a *regional architecture* in the transportation planning arena. Gathering a wide range of stakeholders and developing a regional architecture which responds to local transportation needs and problems can serve as a guiding framework for coordinated development of ITS within a region and will evoke the discussion of operations roles and responsibilities, phasing considerations for planned ITS enhancements, and regional agreements on technology and standards.

Using the National ITS Architecture and ITS standards will provide broad, long-term benefits:

- ***Interoperability:*** The National ITS Architecture has identified where standards are needed for system interoperability (interfaces and products). Because the National ITS Architecture is serving as the common foundation for ongoing ITS standards development work, factoring it into your current system enhancements will facilitate the transition to a standard interface definition in the future. Using standard interfaces will provide a foundation for national and regional interoperability and even interchangeability of some devices used in ITS traffic management, even though they may be from different manufacturers.

- ***Increased competition:*** By requiring use of open standards (non-proprietary), multiple vendors will be able meet the standards and be able to respond to RFPs. Support and upgrades will also be available from multiple potential sources, avoiding the problems of being locked in to one source (e.g., the vendor goes out of business).

- ***Future expandability:*** By designing within a common framework and using open standards, you will create an environment that integrates legacy systems with new ITS applications and allows more functionality to be added as needed.

- ***Lower costs:*** ITS equipment and device compatibility will create larger total markets attracting more suppliers resulting in more capable products at lower prices. The resulting long-term costs of deployment will be pushed down by these economies of scale for off-the-shelf ITS equipment and products and by competition through open-system enabling of multiple vendors.

- ***Increased transportation system integration:*** The open nature and structure of the National ITS Architecture and use of standards-compliant components will make integration of complex traffic management components and regional systems easier. Improved integration of systems operated by different agencies will permit effective information sharing and more effective use of resources. Seamless traveler services across agency lines will become a reality.

- ***Assistance in project development and regional planning activities:*** As evidenced from the above discussion, the National ITS Architecture can be usefully applied to both project development and longer term regional planning activities. Accordingly, this document will address these activities in two separate sections for clarity and ease of reference for the reader.

1.3.2 ITS Standards

Using the National ITS Architecture to plan, design, deploy, and integrate freeway and incident management systems will help ensure that your system will be compatible with existing, planned, and future systems in your region. Your freeway and incident management system will also have an open systems architecture, use industry-accepted standards and interfaces wherever they exit, and will minimize reliance on proprietary information, interfaces, and protocols. Ultimately, these standards will promote national interoperability of some key services to ensure that travelers from outside your region will also be able to benefit from the ITS services you provide. Consistent with the National ITS Architecture, the U.S. DOT is supporting and guiding development of selected ITS standards by funding Standards Development Organizations (SDOs).

1.4 Document Organization and Summary

1.4.1 Document Organization

This document is divided into five major sections with the content of the document as illustrated in Figure 1.4-1.

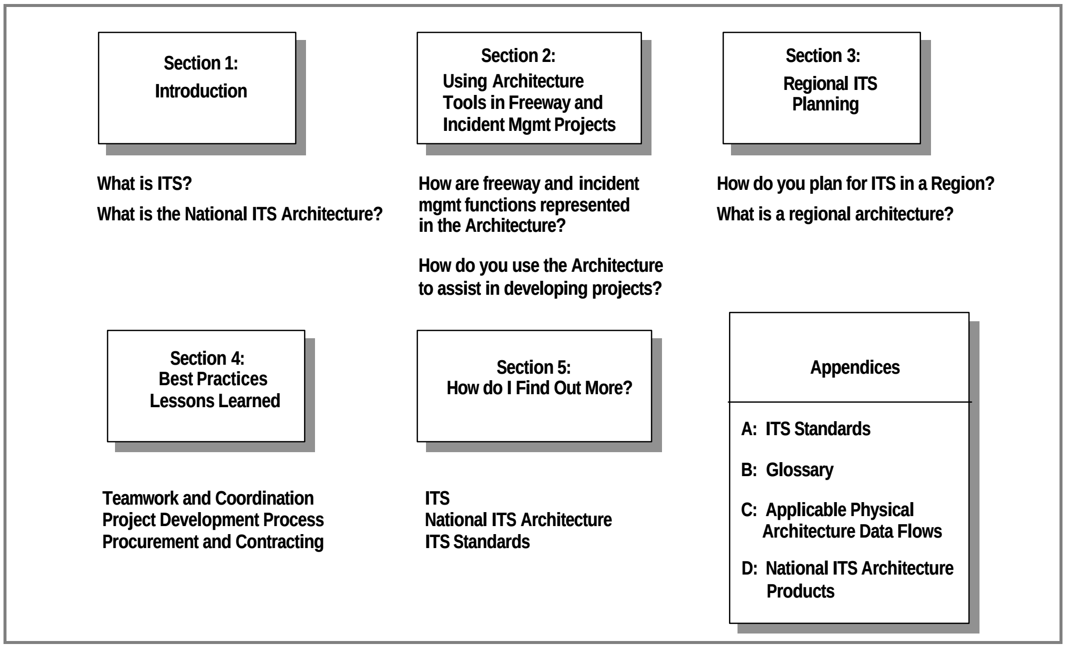


Figure 1.4-1. Document Organization

1.4.2 Document Summary

This document covers many important areas and you are encouraged to read the entire document. However, if you are unable to do so, the summary presented below will point you in the right direction to find the information you are seeking.

For example:

- If you are beginning a major freeway or incident management system project, proceeding to review Sections 2 and 4 might be best.

Ë If you are involved in long-term planning of your transportation system, starting your review with Section 3 might be best.

Section 1: Introduction and Summary

Section 1 briefly discusses ITS, the National ITS Architecture, benefits of freeway and incident management systems, freeway and incident management functions, and briefly discusses capabilities provided by the National ITS Architecture and why you should use it.

- ITS uses a combination of management strategies and computer, communications, surveillance, and control technologies to increase the efficiency of national, regional, and local surface transportation systems.
- There are a growing number of successful freeway and incident management systems yielding benefits with very encouraging cost/benefit ratios.
- Using the National ITS Architecture as a tool in developing your freeway and incident management systems will help provide for ease of additions of interfaces to future subsystems.
- The Architecture supports integration of surface transportation systems. This includes, for example, the integration of freeway and incident management systems with traffic signal control systems, traveler information systems, and electronic toll collection systems.

Section 2: Use of the National ITS Architecture Tools in Freeway and Incident Management Projects

Section 2 identifies the functions of freeway and incident management systems as defined by the National ITS Architecture. The section then explains the key concepts of the Architecture, and how the Architecture can be used to develop freeway and incident management projects. Some representative scenarios are used as examples to help you use the National ITS Architecture.

- The National ITS Architecture provides a common structure for the deployment of ITS; It defines 19 interconnected physical subsystems, the transportation functions each subsystem performs, and the information subsystems exchange with each other to provide 30 user services.
- The functions associated with basic freeway and incident management systems reside in 3 subsystems of the National ITS Architecture: the Traffic Management Subsystem, the Emergency Management Subsystem, and the Roadway Subsystem.
- The National ITS Architecture can be applied to most project development steps, and is particularly helpful in the identification of solutions and the planning and design of the solution.
- The Architecture only defines the transportation management functions that each physical subsystem performs plus the interfaces and data flows between them. Designers have complete freedom in deciding which functions are required for their needs, what equipment to use to implement the transportation management functions, and what technologies will be used. Designers are encouraged to be compatible with the Architecture and with ITS standards to achieve interoperability, to provide for future enhancements and expandability, and to obtain the long-term benefits of higher quality and lower costs from economies of scale.

Section 3: Regional ITS Planning

Section 3 describes planning for ITS applications and formulating ITS projects in a regional context.

- Using the National ITS Architecture provides a good starting point for developing a regional architecture in the transportation planning arena.
- Involving comprehensive representation of regional transportation stakeholders in developing a regional architecture to address needs and problems can produce broad cooperation.
- Developing a regional architecture can guide development of ITS within a region and facilitate agreements on roles and responsibilities, phasing

considerations for implementation of planned ITS capabilities, and regional agreements on technology and standards.

Section 4: Lessons Learned / Best Practices

Section 4 provides advice on developing and implementing freeway and incident management projects using lessons from agencies that have developed and implemented these systems, or are currently developing and implementing ITS projects. Information is provided on various topics that are relevant to the deployment of freeway and incident management systems.

- Stakeholder involvement and coordination, plus teamwork and selecting the right project staff, may be the keys to success on any ITS project. This certainly holds true for freeway and incident management projects, since a number of agencies are ultimately impacted by these projects.

- Transportation agencies face many impediments in the procurement and contracting of ITS projects. Many of the procedures, controls, and measures which were put into place over the years for construction projects have had to be accommodated. However, there is some relief for these impediments. This section sheds some light on the more common problems that have been experienced, and some of the lessons that experience has provided.

Section 5: How Do I Find Out More?

Sections 5 shows readily accessible places to find additional information on ITS, the National ITS Architecture, and ITS Standards.

References

The references pages provide a brief listing of references that may be important to those involved in any of the key roles or activities involved in planning, development and deployment of freeway or incident management systems.

Appendices

Finally, this document contains four appendices: Appendix A discusses ITS Standards; Appendix B provides a Glossary; Appendix C presents the Physical Architecture Data Flows Associated With Freeway and Incident Management Systems; and Appendix D is a synopsis of each of the 16 volumes that make up the National ITS Architecture documentation.

- ITS Standards described in Appendix A are those applicable to freeway and incident management systems. ITS standards have been and are being developed to support the integration of transportation systems. ITS standards should be used to help ensure interoperability of ITS subsystems and devices plus interchangeability of like devices.

- Physical Architecture Data Flows listed in Appendix C indicate the information that is intended by the National ITS Architecture to flow across interfaces of freeway and incident management subsystems with other transportation systems, including those in adjacent jurisdictions.

2. Use of the National ITS Architecture Tools in Freeway and Incident Management Projects

2.1 Overview

This chapter presents the details of how the National ITS Architecture can be applied to freeway and incident management project development activities. An overview of freeway management and incident management system operations and a general project development process is presented first to establish the context for this chapter. Next, the key concepts of the National ITS Architecture are discussed to ensure that the reader understands the fundamentals and structure of the tool. The following section then shows how to apply the National ITS Architecture concepts and databases to the various steps presented in the general project development process. Lastly, two project application scenarios are presented which use realistic examples to illustrate the material presented in the previous sections.

2.2 Freeway Management and Incident Management Operations

Freeway management systems benefit the public with improved traffic flow by optimizing available capacity on freeways. Incident management plays an important role in the restoration of traffic flow and is included in this document for that very reason. It is important to note that incident management systems are not typically systems unto themselves, but rather a collection or matrix of separate and distinct systems or agencies linked by communications.

2.2.1 Freeway Management Operations

A freeway management system consists of elements, or components, used to provide freeway management functions. The typical components of freeway management systems are (1) field equipment, (2) communications equipment, and (3) a traffic management center. In addition, qualified personnel are needed to operate the center and maintain the equipment, and policies need to be established to deal with various transportation-related events (e.g., incidents) that impact the freeway system. It is important to recognize that each freeway management system is tailored to accommodate specific characteristics (political, geographical, roadway, etc.) and needs of the region.

2.2.1.1 Field Equipment

A number of different technologies can be used in the field to monitor traffic conditions, control access and lane utilization, manage incidents, and disseminate information to motorists. Figure 1.2-1 in Section 1.2.1 illustrated the major field components (grouped according to the freeway management function they provide). Within certain components, a variety of technologies can be employed. For example, vehicle detection within the surveillance function can be accomplished by using inductive loop detectors, microwave or radar sensors, automatic vehicle identification or location, video imaging, or other technologies depending on the type of data desired. Alternative technologies also exist for the other functions of lane use control, incident management, information dissemination, ramp control, and HOV treatment.

2.2.1.2 Communications Equipment

The communications components connect the field devices with each other and with the traffic management center components. In some cases, commands and other data are sent from the management center to the field components.

A number of technologies are available to provide communications between the field components and the management center. The two basic categories are (1) wireline, and (2) wireless transmissions. The types of wireline transmissions include fiber optic, coaxial, and twisted pair; wireless transmissions include infrared, microwave, narrow band or spread spectrum radio, cellular telephone, and citizen band radio. A combination of these two communications categories may be needed for end-to-end transmission between the management center and the field components.

2.2.1.3 Traffic Management Center

The traffic management center is the hub of a freeway management system. It is the place where information about the freeway system is collected, processed, and organized, and is often the place where control strategies are determined, coordinated with other agencies, and carried out.

The major components of the traffic management center are the display and control interfaces that link the center to the field components (via the communications components). Human operators can also be considered major components of the traffic management center. Human operators monitor freeway conditions and make control adjustments to enact applicable management strategies and maximize the efficiency of the freeway system.

2.2.2 Incident Management Operations

The following sections provide brief descriptions of the typical roles and responsibilities of agencies involved with incident management. It should be emphasized that effective incident management is facilitated by a planned coordinated regional approach that considers institutional and technological issues of multiple jurisdictions, response agencies, and service providers.

2.2.2.1 Agency Roles and Responsibilities

The agency roles, responsibilities and processes that are described below are not to be considered representative of all metropolitan areas, nor are they recommendations. It is understood that the processes associated with incident management and emergency services provision vary from region to region. The descriptions below are intended to illustrate the generic roles, responsibilities, and processes of all agencies and service providers (i.e., emergency medical services, police, fire, towing service) involved with incident management activities.

Law Enforcement

Law enforcement services often are provided by a number of organizations, including State Police and Highway Patrol, County Police, Deputy Sheriffs, Constables; and local police. Officers enforce the statutory authority of the Incident Commander (IC) to direct the activities of the general public, including motorists and passengers, as well as bystanders. As peace officers, they bring the ability to control scene activities and to arrest and remove violators who hamper emergency operations. The IC utilizes law enforcement in roles well-suited to their repetitive capabilities, typically including traffic control and

direction, bystander and crowd control, perimeter establishment and enforcement, accident investigation, and crime scene management. Law enforcement personnel are often also utilized in non-traditional roles as well, primarily dictated by the demands of the incident and availability of resources. Officers commonly provide first aid, perform emergency extrication, meet with the media, coordinate with traffic management, manage evacuations, and participate in many other activities. Law enforcement is usually involved in highway incidents. Law enforcement is usually not a contracted service

Fire and Rescue

These services are provided by the local fire department and by surrounding fire departments through mutual aid agreements. In some areas, the fire department consists of a private corporation providing services under contract to a jurisdiction. Often delegated the authority to command any incident involving fire, entrapment, injury, or hazardous materials, officers direct all resources at such incidents. Fire and rescue can provide many incident services, including fire suppression, extrication, hazardous materials release control, technical rescue, and water rescue. Emergency medical services can also be incorporated into the fire department, however when organized separately, they are often referred to as the “Third Service.” The highest priority situations addressed by fire and rescue organizations at a highway incident are those affecting life safety, followed by those affecting the environment, and finally by those concerning property damage. Fire and rescue personnel are rarely used outside of their primary specialties. They can be quite versatile in performing their many roles and responsibilities.

Emergency Medical Services

Emergency Medical Services (EMS) are exclusively concerned with the triage, treatment, and transport of patients. In many areas, EMS is provided under contract to local jurisdictions. In some instances, it is partially or fully incorporated within the fire department. EMS personnel work under the direction of licensed medical authority, usually situated at a hospital trauma center, and follow set protocols. EMS supervisors often assume command, especially at complicated medical incidents.

Transportation is an important EMS capability, and usually both ground and air emergency medical transportation are provided. EMS personnel are almost never utilized for other than medical activities.

Transportation Agencies (including Service Patrols)

Transportation agencies typically plan and coordinate the overall incident management program. In the event of an incident, they often provide transportation operations center functions and assist in incident detection and verification. Transportation agency service patrols assist in accident clearance, determine roadway repair needs, assist disabled motorists, and coordinate response efforts with other agencies. They may also provide traffic control. Agency operations centers may provide motorists and information service providers with accident information, identify alternate routes, and re-route traffic.

The transportation agency will assess any infrastructure damage, arrange for emergency repair with a district maintenance office, identify responsibility for highway damage to seek compensation for repairs, provide infrastructure repair time estimates to the TMC, and take steps to return the roadway to full capacity as soon as possible.

Towing Service

Professional towing services are often the experts on how to unstack wrecked or overturned vehicles. They also provide recovery services for large truck incidents including the transfer of loads.

Public Works Departments

Public Works usually provides assistance in infrastructure repair, such as guardrails and light standards. They may also provide traffic control for long-term closures, and provide equipment for scene cleanup.

Information Service Providers (ISPs)

Information Service Providers (ISP) are usually commercial entities that provide traffic information updates to both motorists and the media. However, some ISP functions within the context of the National ITS Architecture may also be performed by public agencies. ISPs may use a variety of methods to disseminate information to travelers, including broadcast radio, traffic hotlines, cable TV traffic alerts, e-mail services, Internet web sites, or pager services.

Media

The broadcast media typically report traffic incidents, broadcast delays, provide alternate route information, and, if the incident is particularly severe, update incident status frequently. The media provides the primary means for the IC, through the

Public Information Officer, to disseminate information to the public. News-making events, warnings, rumor control items, and alerts are handled this way.

2.2.2.2 Incident Management Activities

The following describes typical incident management activities and how various agencies may interact in an incident. Although the use of some ITS technologies are described here, a more extensive description of the application of ITS technologies for incident management is provided in the scenario in Section 2.6.1.

In general, incident management begins with the notification or detection of an incident and progresses through to incident clearance. Although the sequence often differs, the elements described below are usually part of the incident chain of events. An illustration of the typical flow of communications related to highway incident response is provided in Figure 2.2-1.

Notification

The notification of an incident on a freeway is often generated by numerous phone calls, typically mobile cellular telephone calls, to Public Safety Answering Points (PSAPs). PSAP call-takers will notify dispatchers at the appropriate emergency response agencies (e.g., fire and rescue, law enforcement, EMS, etc.). The dispatchers will then contact the appropriate emergency response facilities (e.g., police stations, fire houses, ambulance centers, hospitals, etc.). If the emergency response vehicles are not present at the facility, the dispatcher will directly contact the vehicle.

Detection and Verification

Occasionally, detection of the incident will come from a TMC operator who has noticed a decreased traffic flow through a loop detector or CCTV field link. The TMC operator will then notify the PSAP for appropriate action. Typically, actual verification of an incident takes place at the incident scene and is performed by the first responding unit. Occasionally, dispatchers may request that a TMC attempt to verify the location or type of incident, especially when they have received vague or conflicting reports by phone.

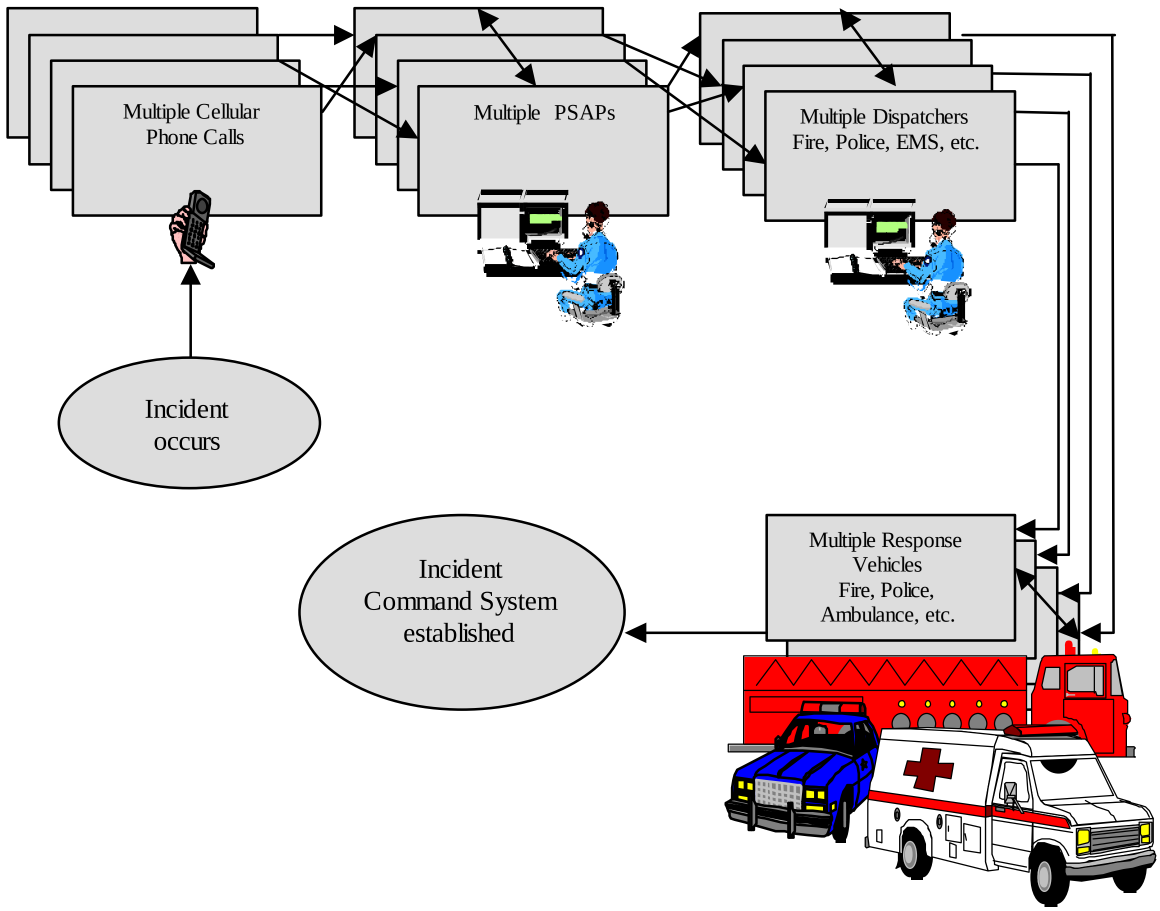


Figure 2.2-1 - Example Configuration of Communications for Freeway Incident Response

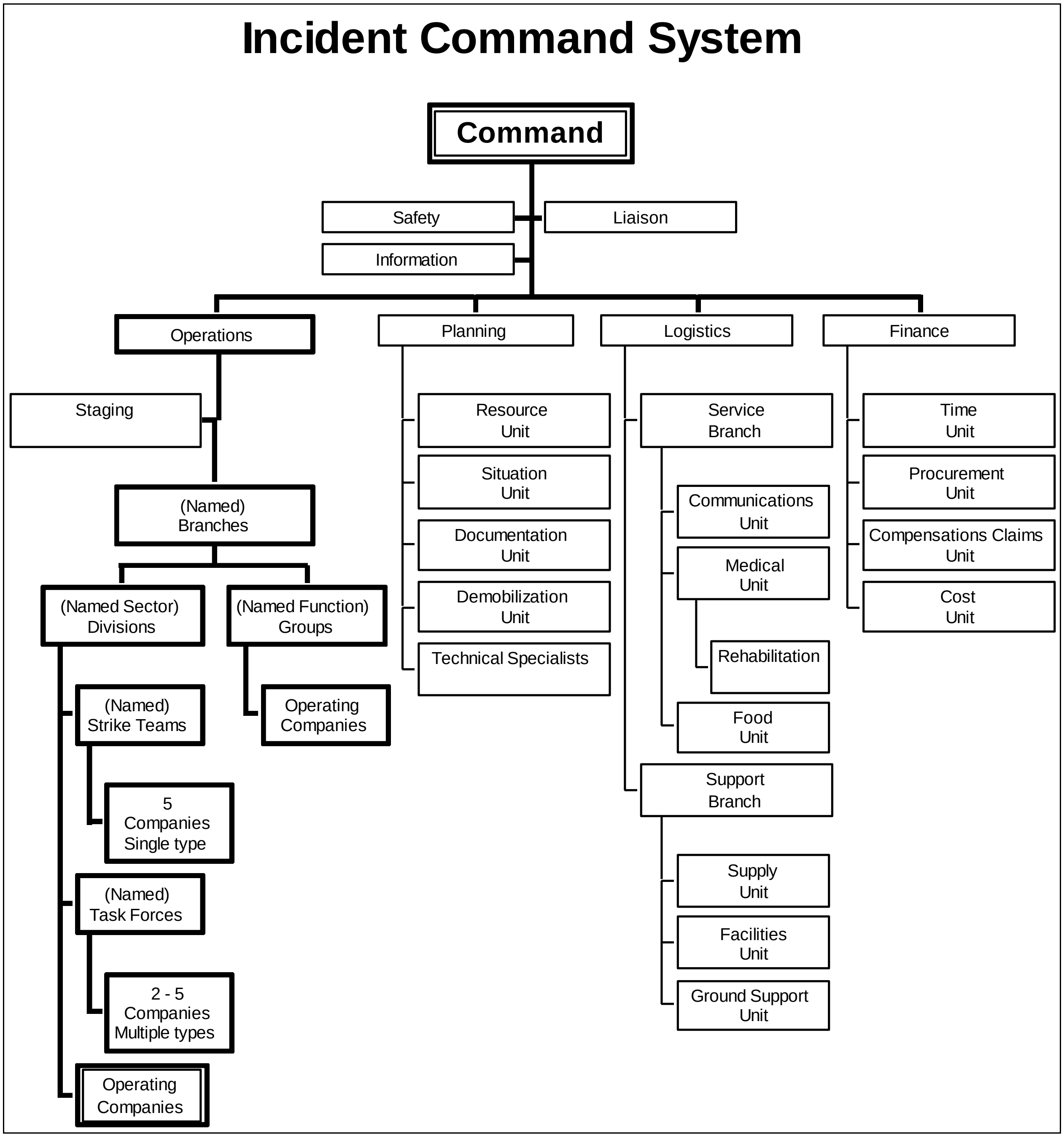


Figure 2.2-2 Fully Expanded Generic Incident Command System Structure

Incident Response

The dispatcher alerts the appropriate emergency response agencies via voice and alarm systems and, in some jurisdictions, automatic data transfer. A sample organization chart for an Incident Command System is shown in Figure 2.2-2.

Incident Scene Management

The nature of the incident and its location pre-determines jurisdiction and who assumes the responsibilities of Incident Commander (IC). The IC has overall responsibility and authority for coordinating the prosecution of an incident. The Incident Commander first establishes command upon arrival at the scene. The priorities that the IC will follow for the incident scene management are (in order):

- Life safety (of responders and public)
- Property conservation (private, public and the environment)
- Stabilization of the incident (ensure the risk to life safety and property does not increase)
- Restoration of traffic flow

The IC assumes control of the incident scene, operating under the authority of applicable statutes to direct emergency responders, passers-by, and onlookers. There may have been someone previously directing activities, such as a Good Samaritan, tow truck operator, truck driver, off-duty medical personnel, or any assertive private citizen. The IC will debrief such an individual and obtain as much information as possible before releasing them (as he will do for his replacement).

Through his own observation and aided by subsequently arriving units, the IC ascertains the nature, extent, and severity of the incident. He will organize and deploy whatever effort is needed to rectify the situation. As the situation changes, the IC will reorganize the Incident Command System (ICS), reassign on-site units, request additional resources, or release assigned resources, maintaining a suitable on-scene action organization that most efficiently addresses the priorities of the incident. This general approach is usually followed for most emergency incidents (those involving a fire, a crime in progress, or a life-threatening injury), and is even beginning to see use in the non-emergency arena as well.

The scope of the IC's attention is centered on the incident, typically no more than a few hundred feet from the perimeter of the emergency activity area. The effects can extend for many miles beyond that, such as with traffic backing up on a freeway system or with drifting plumes of smoke or other hazardous material. The incident has usually caused significant traffic congestion, which hampers the response of resources through that congestion to remedy the problem. Ingress routes must be cleared to enable emergency responders to reach the scene. Egress routes must be held open to allow for patient transport, evacuation, retreat, and redeployment. Staging areas must be set up so that apparatus and crews may be closely positioned to the incident and able to quickly respond if needed. For large incidents, bases or camps may need to be set up. Traffic management and operations centers would typically coordinate and manage efforts to alleviate these widespread traffic and highway-related problems, and would work with the IC's dispatch center.

For large incidents that involve several jurisdictions, or that cover large areas, or that are multi-hazard, a contributory form of ICS will be established—the Unified Incident

Command System. In this incident organization format, all involved agencies participate in the command process. Even still, only a single IC directs activities. For major incidents, the disaster or emergency management organizations commence operations, typically establishing an Emergency Operations Center to manage an entire county, for example.

Traffic Management

Consideration is given to activating planned alternate routes if required based upon estimation of the length of the delay. After determining that alternate routes should be used, the operations center:

- Activates field devices that support the operation of the alternate routes (i.e., VMS and HAR)
- Informs the media and ISP about the recommended use of alternate routes
- Contacts local agencies and other TMCs to inform them of the use of planned alternate routes in their jurisdiction
- Where possible, observes the operation of the alternate routes through the use of detection and surveillance devices (e.g., loop detection and CCTV).

Traffic control systems such as variable message signs or highway advisory radio are activated by the operations center upon verification that the blockage has occurred, even before responders arrive. A service patrol is dispatched to the incident scene with a portable VMS to assist in controlling traffic. Service patrols may also assist police in setting up signs, cones, and flares to warn motorists before they reach the backed up traffic. Police provide manual traffic control. Guidance is given to other responders via radio communications on the best method to access the scene (left shoulder, right shoulder, opposite lanes, etc.). DOT personnel coordinate a traffic control plan with police and fire department. After secondary accident concerns are resolved, a plan is devised for routing traffic through the scene.

Incident Clearance

Equipment for removing the damaged vehicles is requested by the police and is provided by private towing and recovery service providers. The police provide the towing and recovery operator with as much information related to the accident scene as possible to ensure that the proper equipment is dispatched to the scene. Once on the scene, the towing and recovery operator may provide police with recommendations on the order and manner in which vehicles should be removed with the objective of increasing traffic flow through the scene. Consideration may also be given to leaving disabled vehicles on the side of the road until the peak hour is over. Private tow truck operators, and the DOT service patrol personnel also clean up any debris that remains on the roadway.

Motorist Information

Motorist information is provided by the operations center through links with the media, ISP, VMS, and HAR. The operations center maintains communications with the police and monitors radio traffic at the incident. Close contact is maintained with the DOT spokesperson at the incident. Estimated clearance times as well as updates are provided when traffic conditions change such as additional lane openings.

Given the interagency aspect of both freeway management and incident management activities, developing and deploying projects that will aid these functions and ensure coordination across agencies is critical. The next section addresses such project development.

2.3 Development of Freeway and Incident Management Projects

Transportation agencies go through a variety of steps and processes in developing and deploying transportation improvement projects. The nature and level of formality of these processes depends on the scope of the project, state and local procedures, funding requirements, and legislative requirements, among other things. However, there are certain fundamental steps that are fairly common across these processes. These basic steps include:

1. Identification of transportation needs or problems
2. Identification of potential solutions to the problem
3. Planning and design of solutions to the problem
4. Funding, procurement, and implementation of the solution to the problem

Each step of this development process is briefly described below as it relates to transportation issues that agencies involved with freeway management and incident management may experience.

2.3.1 Identification of Needs or Problems

Typically the first step an agency takes in developing and implementing a project is the identification of existing transportation needs, objectives, or problems. These may be identified through a number of activities, whether through a traditional transportation planning process, public questionnaire, a problems/needs identification study, or an ITS Early Deployment Planning (EDP) process. For example, an agency may identify a particular section of roadway that has frequent delays due to an unusually high rate of incidents.

2.3.2 Identification of Solutions

Based on the identified problem in this example, delays on a section of roadway with a high occurrence of incidents, the agency will identify potential solutions to the problem. Potential solutions to this particular problem may include:

- Implementing call boxes for quicker detection of incidents
- Establishing more service patrols for quicker incident response
- Implementing CCTVs for quicker, more accurate detection, verification, and response to incidents
- Developing and implementing a cellular call-in solution

2.3.3 Planning and Design of the Solution

Once an optimal solution to the problem has been identified, the agency typically begins a process of planning and designing the solution or system. The planning phase may include activities such as determining implementation or phasing strategies, and identifying and securing of funding sources. The design phase may include activities such as preparing detailed specifications (for hardware, software and communications) and designing systems configurations.

2.3.4 Funding, Procurement and Implementation

Once the agency has identified the most feasible solution to the transportation challenge, the system or portion of a system is procured. The traditional approach to procurement is a two-step process: (1) the letting and completion of a contract to retain architect/engineering services to prepare detailed design specifications for the facility and (2) the letting and completion of a separate contract for the construction of the project. Due to the rapidly changing and technological nature of ITS, the system manager approach to procurement can also be used. In this case, the system manager performs the design and writes the specifications. The hardware and construction is bid in the conventional manner, but the system manager remains to develop the software, integrate all the different components, and provide documentation and training for the operating personnel. See Section 4 for a discussion of these and other procurement alternatives.

A successful process will result in the desired objectives (which respond to the problems and needs that are identified in the first step) being satisfied by the implemented system. Successful operations of the system (often overlooked during the project development process) over a sustained period of time is the true indicator of how well the overall process worked.

2.4 Key Concepts of the National ITS Architecture

The National ITS Architecture is available as a resource for any region and will continue to be maintained by the U.S. DOT independently of any specific system design or region in the nation. It represents the work and collective thinking of a broad cross-section of the ITS community (systems engineers, transportation practitioners, technology specialists, system developers, consultants, etc.) over several years. As such, the National ITS Architecture contains material that will assist agencies at each step of project development (which will be presented next in Section 2.5). It will also clarify how an individual project, such as a freeway or incident management project, fits into a larger regional transportation management context (to be discussed further in Section 3).

Because of the extensive geographic and functional scope of the National ITS Architecture and the requirements which drove its development, it is structured somewhat differently and uses different terminology than is typically used today in the transportation community. It was developed to support ITS implementations over a 20-year time period in urban, interurban, and rural environments across the country. Accordingly, general names were given to the physical transportation system components and locations in order to accommodate a variety of local design choices and changes in technology or institutional arrangements over time. This allows the general structure of the National ITS Architecture to remain stable while still allowing flexibility and tailoring at the local implementation level. This difference in language can be easily overcome with a better understanding of how the National ITS Architecture is organized and how it relates to familiar systems of today.

As background, this section explains the essential terminology and concepts needed to understand, navigate, and use the National ITS Architecture and then provides a summary of the key documents produced under the National ITS Architecture development effort which will be referred to in the next section. The portions of the material that are particularly relevant to freeway and incident management are also highlighted. The reader who is already familiar with the National ITS Architecture may wish to skip ahead to the next section for information on how to use this information and methodology in the context of project development. The following concepts and terms are explained in this section:

- User Services and User Service Requirements (2.4.1)
- Logical Architecture (2.4.2)
- Physical Architecture (2.4.3)
- Equipment Packages (2.4.4)
- Market Packages (2.4.5)

2.4.1 User Services and User Service Requirements

User services represent what the system will do from the perspective of the user. A user might be the public or a system operator.

Table 2.4-1 presents the 30 user services, which formed the basis for the National ITS Architecture development effort, grouped into seven bundles for convenience. A collaborative process involving USDOT and ITS America with significant stakeholder input jointly defined these user services. Clearly, a different set could have been defined. The important point is that the concept of user services allows the process of system or project definition to begin by thinking about what high level services will be provided to address identified problems and needs. The bolded entries in the table are most relevant to freeway and incident management systems.

A number of functions are required to accomplish each user service. To reflect this, each of the user services was broken down into successively more detailed functional statements, called *user service requirements*, which formed the fundamental requirements for the National ITS Architecture development effort. For example, the traffic control user service is actually defined by over 40 “functions” (the hierarchy of functional requirements makes it difficult to provide an exact number). In the Traceability Matrix of the National ITS Architecture documentation, the user service requirements can be reviewed. Many of these user service requirements can be implemented today, although some of them may be more representative of future capabilities and should be deferred for now. These requirements can be used as a departure point for the development of project functional requirements and system specifications, as will be discussed in Section 2.5.

Table 2.4-1. User Services for the National ITS Architecture

User Service Bundle	User Service
Travel and Transportation Management	**En-Route Driver Information** Route Guidance Traveler Services Information **Traffic Control** **Incident Management** Emissions Testing and Mitigation Highway-Rail Intersection
Travel Demand Management	Pre-Trip Travel Information Ride Matching and Reservation Demand Management and Operations
Public Transportation Operations	Public Transportation Management En-Route Transit Information Personalized Public Transit Public Travel Security
Electronic Payment Services	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance Automated Roadside Safety Inspection On-Board Safety Monitoring Commercial Vehicle Administrative Processes **Hazardous Material Incident Response** Commercial Fleet Management
Emergency Management	**Emergency Notification and Personal Security** **Emergency Vehicle Management**
Advanced Vehicle Control and Safety Systems	Longitudinal Collision Avoidance Lateral Collision Avoidance Intersection Collision Avoidance Vision Enhancement for Crash Avoidance Safety Readiness Pre-Crash Restraint Deployment Automated Highway Systems

Table 2.4-2 provides an illustration of user service requirements using an excerpt from the incident management user service.

Table 2.4-2. Example of User Service Requirements: Excerpt from Incident Management

1.7 INCIDENT MANAGEMENT
1.7.0 [ITS] shall include an Incident Management (IM) function. Incident Management will identify incidents, formulate response actions, and support initiation and ongoing
coordination of those response actions. Six major functions are provided which are (1)
Scheduled Planned Incidents, (2) Identify Incidents, (3) Formulate response Actions, (4) Support Coordinated Implementation of Response Actions, (5) Support Initialization of Response to Actions, and (6) Predict Hazardous Conditions.
1.7.1 Incident Management shall provide an incident identification function to identify incidents.
1.7.1.1 The incident identification function shall include the capability to identify predicted incidents.

2.4.2 Logical Architecture

A logical architecture is best described as a tool that assists in organizing complex entities and relationships. It focuses on the functional processes and information flows of a system. The development of a logical architecture helps identify the system functions and information flows, and guides development of functional requirements for new systems and improvements. A logical architecture should be independent of institutions and technology, i.e., it should not define where or by whom functions are performed in the system, nor should it identify how functions are to be implemented.

The logical architecture of the National ITS Architecture defined a set of functions (or processes) and information flows (or data flows) that respond to the user service requirements discussed above. Processes and data flows are grouped to form particular transportation management functions (e.g., manage traffic) and are represented graphically by data flow diagrams (DFDs), or bubble charts, which decompose into several levels of detail. In these diagrams, processes are represented as bubbles and data flows as arrows. Figures 2.4-1 and 2.4-2 depict simplified data flow diagrams from the National ITS Architecture documents. Note that each bubble in the logical architecture is a process that describes some logical function to be performed.

For example, as shown in Figure 2.4-1, at the highest level of the National ITS Architecture, the manage traffic process (which includes traffic control and incident management functions) interacts with seven other processes, including the manage emergency services process (another piece of incident management).

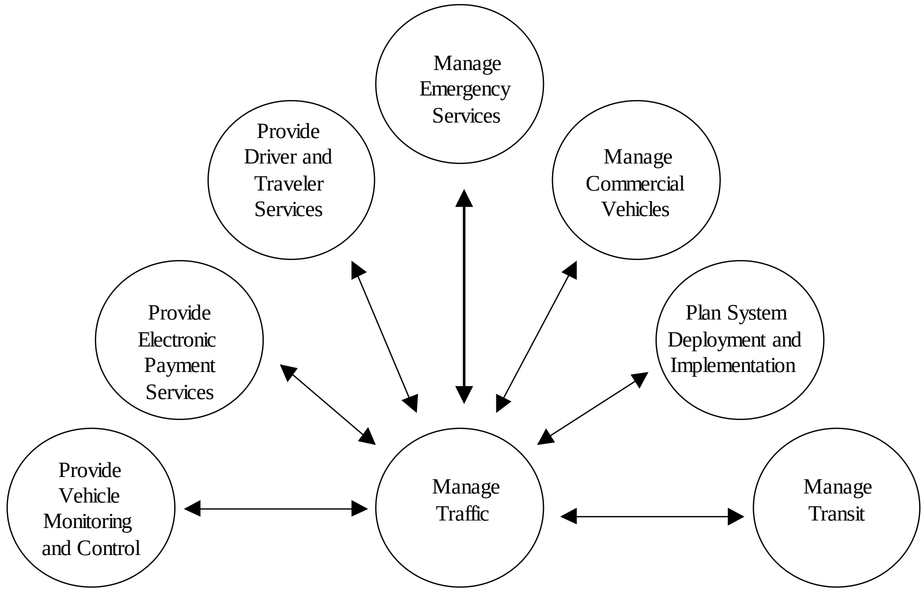


Figure 2.4-1 The Eight Major Processes Within the Logical Architecture

Figure 2.4-2 illustrates how the manage traffic process is then further broken down into five sub-processes; how one of those processes, Manage Incidents, is broken down into seven sub-processes; and so on. Each of these processes is then broken down even further so that a complete functional view of a system emerges. At the lowest level of detail in the functional hierarchy are the *process specifications* (referred to as *P-specs* in the documentation). Figure 2.4-2 shows an example of a process specification (Provide Traffic Operations Personnel Incident Data Interfaces) within the functional decomposition. These process specifications can be thought of as the elemental functions to be performed in order to satisfy the user service requirements (i.e., they are not broken out any further). The information exchanges between processes and between P-specs are called the (logical) *data flows*.

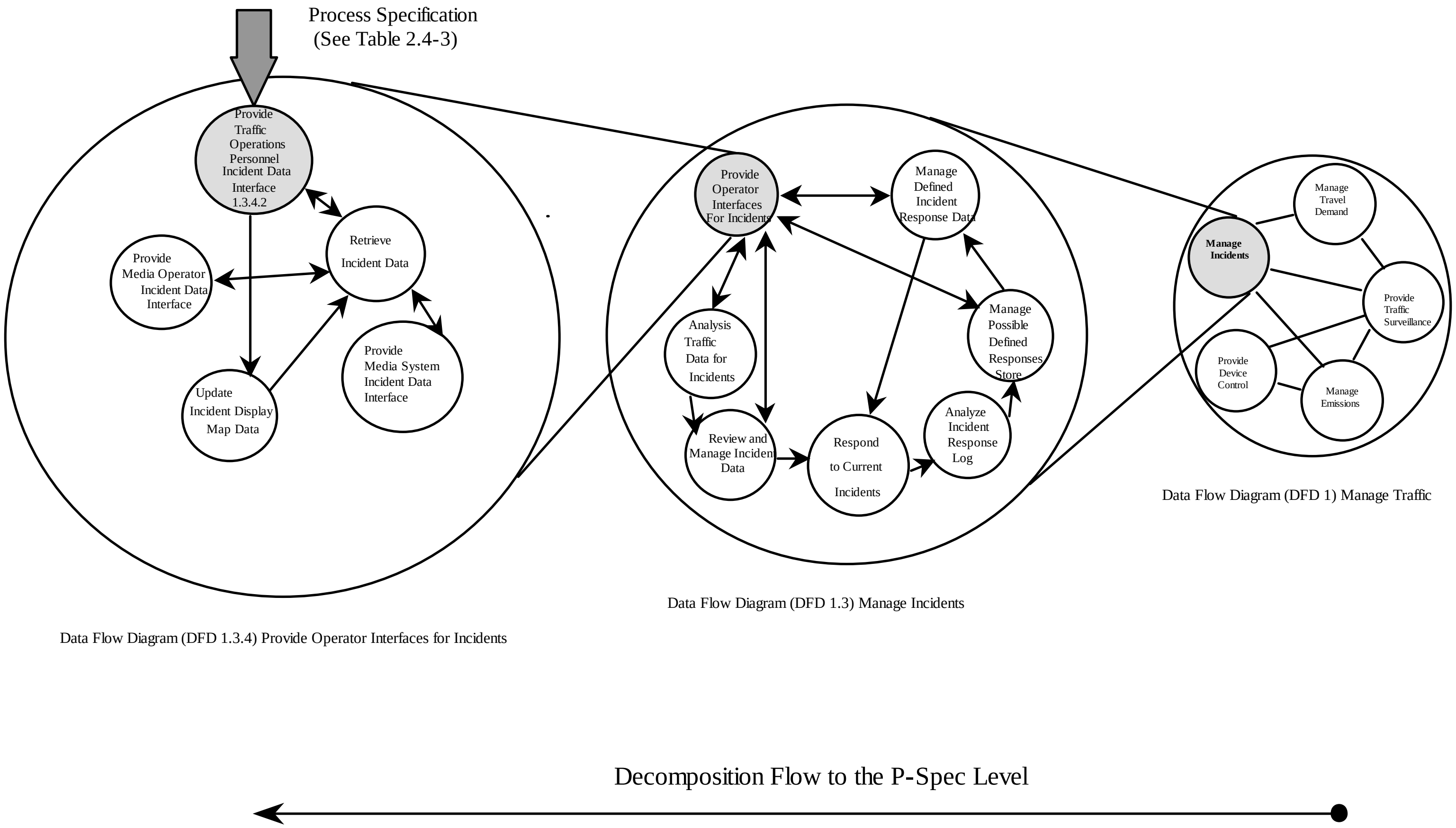


Figure 2.4-2. Example of Logical Architecture Functional Decomposition

Example overview descriptions of process specifications relevant to freeway management or incident management systems are given below:

Table 2.4-3. Example Process Specifications (Overview Descriptions)

Process Traffic Data (P-Spec 1.1.2.2)

Overview: This process shall be responsible for collecting all of the processed data supplied from traffic sensors and from sensors at HRIs. The process shall distribute it to processes in the Provide Device Control facility responsible for freeway, highway rail intersections, parking lot, ramp and road management. It shall also send the data to another process in the Provide Traffic Surveillance facility for loading into the stores of current and long term data.

Select Strategy (P-Spec 1.2.1)

Overview: This process shall be responsible for selecting the appropriate traffic control strategy to be implemented over the road and freeway network served by the Manage Traffic function. The strategy shall be selected by the process from a number that are available, e.g. adaptive control, fixed time control, local operations, etc. The selected strategy shall be passed by the process to the actual control processes for implementation according to the part of the network to which it is to be applied, i.e. roads, freeways, ramps and parking lots. When part of the selected strategy, or at the request of the traffic operations personnel, the process shall send commands to the traffic sensor data process to change the operating parameters of video cameras used to provide traffic data. The process shall make it possible for the current strategy selection to be modified to accommodate the effects of such things as incidents, emergency vehicle green waves, the passage of commercial vehicles with unusual loads, equipment faults and overrides from the traffic operations personnel. The selected strategy shall be sent to the process within the Provide Traffic Surveillance facility responsible for maintaining the store of long term data.

Determine Indicator State for Freeway Management (P-Spec 1.2.2.1)

Overview: This process shall be responsible for implementing selected traffic control strategies and transit vehicle overall priority on some or all of the indicators covering the freeway network served by the Manage Traffic function. It shall implement the strategies only using the indicators (variable message signs (vms), etc.) that are specified in the implementation request and shall coordinate its actions with those of the process that controls the road network. The process shall also be capable of monitoring the extra inputs that will arise where tunnels are involved, including the detection of fire and the consequent requirement to re-route traffic.

Determine Indicator State for Road Management (P-Spec 1.2.2.2)

Overview: This process shall be responsible for implementing selected traffic control strategies and transit priority on some or all of the indicators covering the road (surface street) network served by the Manage Traffic function. It shall implement the strategies only using the indicators (intersection and pedestrian controllers, variable message signs (vms), etc.) that are specified in the implementation request and shall coordinate its actions with those of the processes that control the freeway network and the ramps that give access to the freeway network.

Analyze Traffic Data for Incidents (P-Spec 1.3.1.1)

Overview: This process shall be responsible for analyzing and looking for anomalies in the data continuously received from traffic and from vehicle probes in the road (surface street) and freeway network served by the Manage Traffic function. The process shall pass on any anomalies that it detects to another process in the Manage Incidents facility as possible incidents.

Analyze Incident Response Log (P-Spec 1.3.7)

Overview: This process shall be responsible for periodically analyzing the data in the log of incident responses within the Manage Incidents facility of the Manage Traffic functions. The process shall analyze the log in such a way that possible standard defined incident responses can be determined from the data it contains. Any such possible standard responses that are determined shall be passed by this process to the process that manages the store of possible defined responses.

2.4.3 Physical Architecture

A physical architecture is the physical (versus functional) view of a system. A physical architecture provides agencies with a physical representation (though not a detailed design) of how the system should provide the required functionality. A physical architecture takes the processes (or P-specs) identified in the logical architecture and assigns them to physical entities (called *subsystems* in the National ITS Architecture). In addition, the data flows (from the logical architecture) that originate from one subsystem and end at another are grouped together into (physical) *architecture flows*. In other words, one architecture flow may contain a number of more detailed data flows. These architecture flows and their communication requirements define the *interfaces* required between subsystems, which form the basis for much of the ongoing standards work in the ITS program. Development of a physical architecture will identify the desired communications and interactions between different transportation management organizations. Figure 2.4-3 depicts the relationship between the logical and physical architecture.

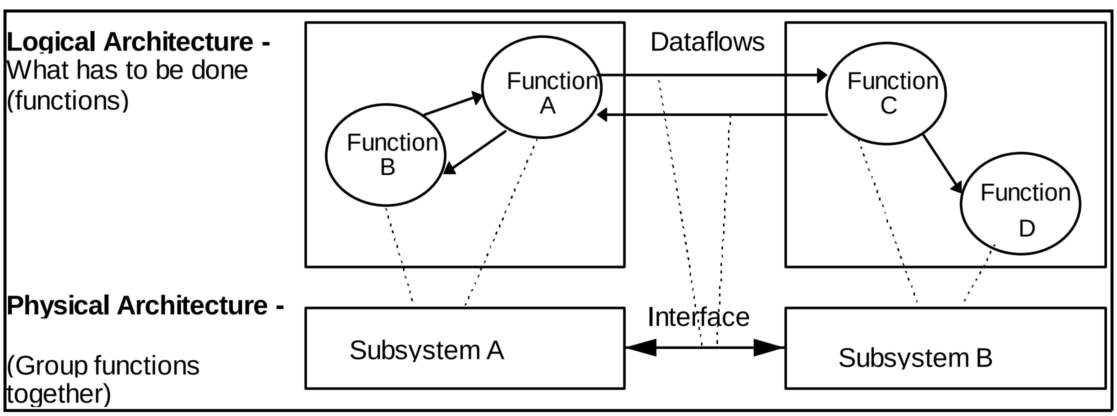


Figure 2.4-3 Representative Logical and Physical Architecture

In the National ITS Architecture, the physical architecture is described by two layers: the transportation layer and the communications layer. Each of these is briefly described below.

<u>Transportation Layer</u>

The transportation layer of the physical architecture shows the relationships among the transportation-management-related elements. It is composed of subsystems for travelers, vehicles, transportation management centers, and field devices, as well as external system interfaces at the boundaries (called *terminators* in the documentation). It may include:

- Field devices for traffic surveillance and motorist information dissemination
- Traffic signal and ramp metering controllers
- Transportation management centers
- Emergency management centers

Communications Layer

The communications layer of the physical architecture shows the flow of information and data transfer for the transportation layer components. This layer depicts all of the communications necessary to transfer information and data among transportation entities, traveler information and emergency service providers, and other service providers such as towing and recovery. The communications layer clearly identifies system interface points where national standards and communications protocols can be used.

Institutional Implications

While an institutional layer is not actually part of the physical architecture, the physical architecture cannot be fully defined in a region without some decisions being made regarding the jurisdictional structure and working relationships that will provide a framework for ITS planning and implementation. These institutional decisions should lead to depiction of who should communicate with whom, and what information should be communicated in the transportation and communications layers, and will vary based on the unique needs and characteristics of a region.

Figure 2.4-4 from the National ITS Architecture, shows the 19 transportation subsystems (white rectangles) and the 4 general communication links (ovals) used to exchange information between subsystems. This figure represents the highest level view of the transportation and communications layers of the physical architecture. The subsystems roughly correspond to physical elements of transportation systems and are grouped into 4 classes (gray rectangles): Centers, Roadside, Vehicles and Travelers.

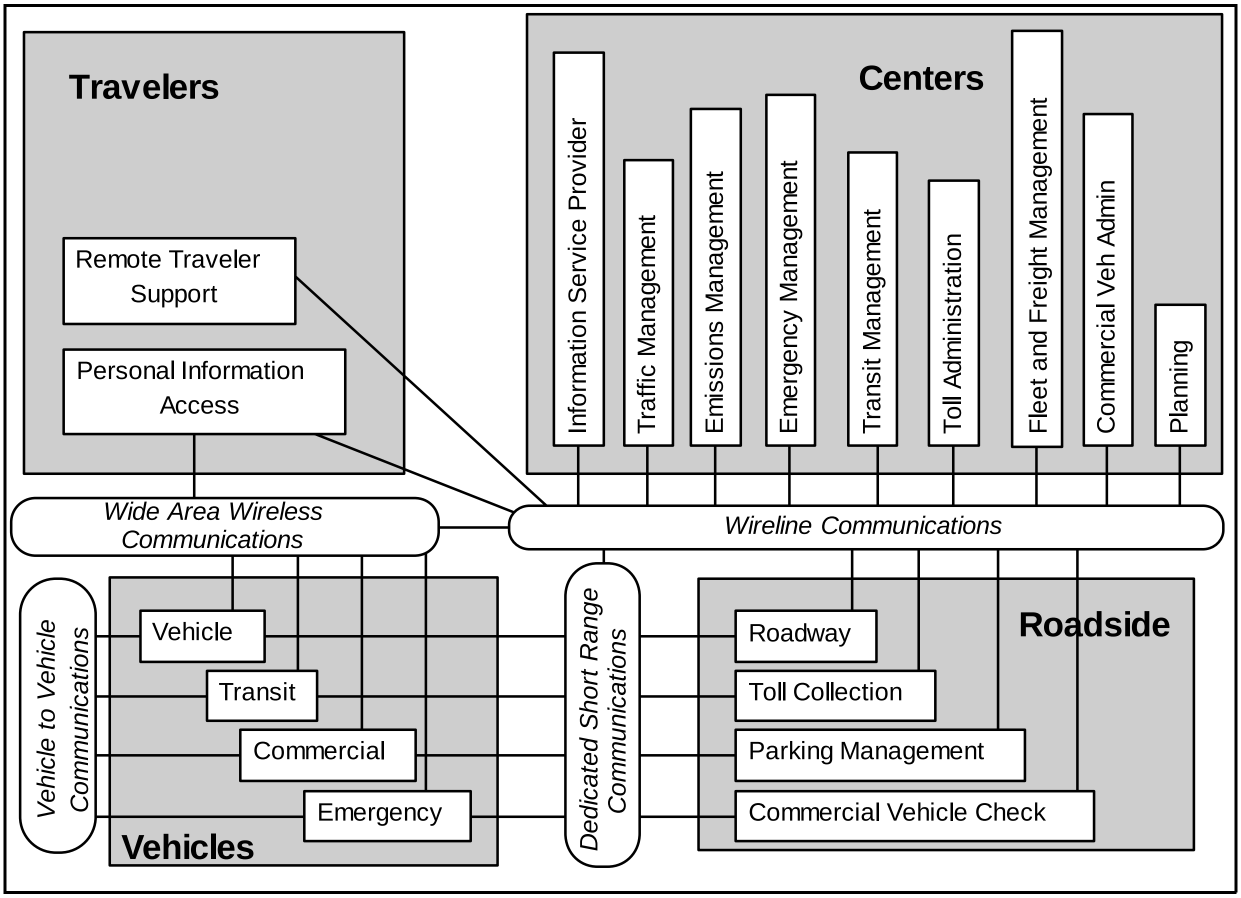


Figure 2.4-4. National ITS Architecture Subsystems and Communications

Basic freeway management systems are represented by functions within 2 of the 19 subsystems: the Traffic Management subsystem and the Roadway subsystem. Incident management systems also include some functions of the Emergency Management subsystem. This is illustrated in Figure 2.4-5, which depicts freeway management system elements as an overlay to the diagram just presented.

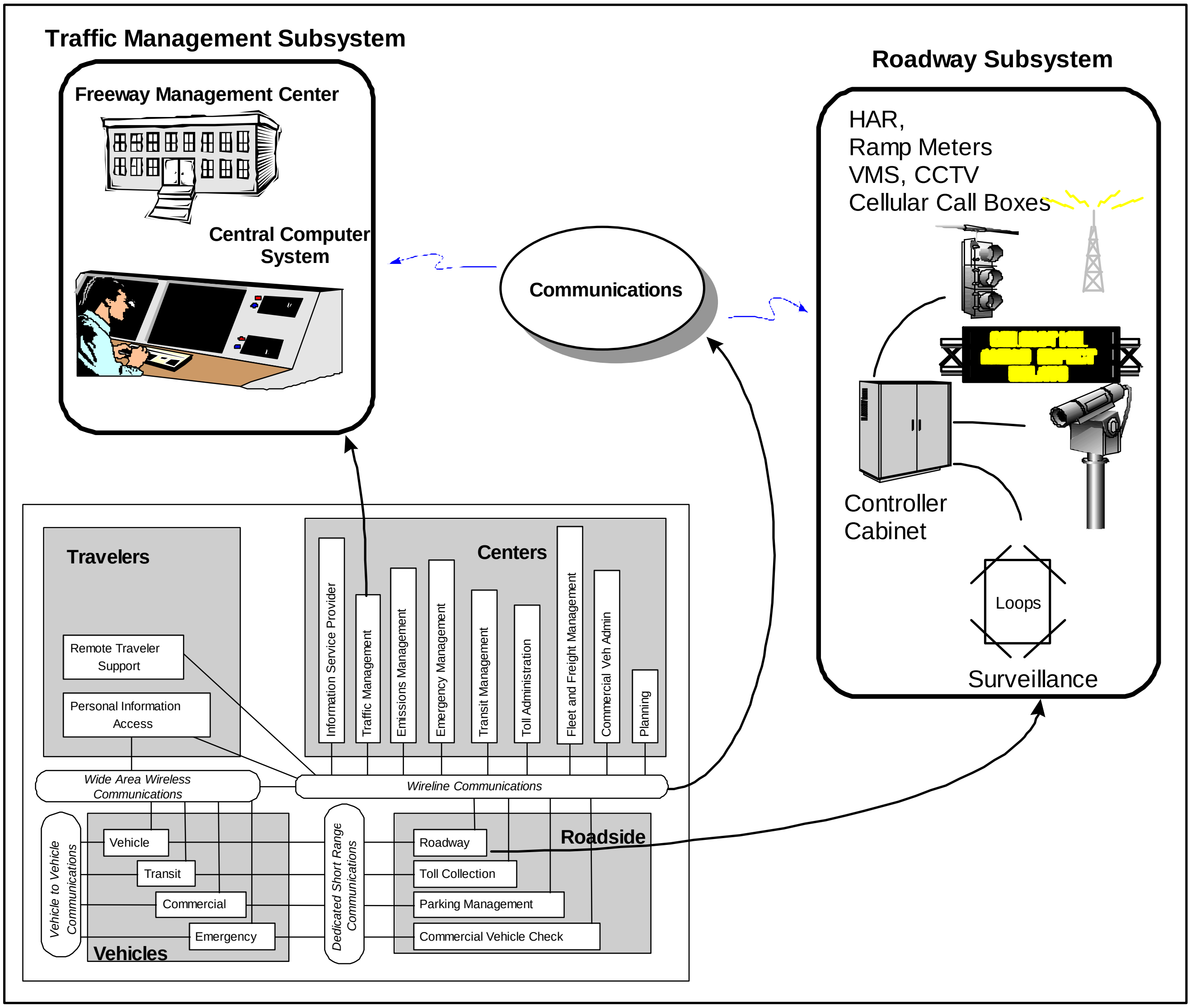


Figure 2.4-5. Basic Freeway Management System Architecture Depiction

These 2 subsystems, together with the necessary communications to exchange control and surveillance information, provide the following capabilities typically associated with freeway management and/or incident management systems:

- Monitor Freeway Conditions
- Identify Flow Impediments
- Ramp Metering/Lane Controls
- Highway Advisory Radios/Variable Message Signs

- Incident Detection/Verification
- Incident Response/Clearance

The Traffic Management subsystem functions are implemented with central equipment typically found in traffic management centers; e.g., computers, traffic control consoles, and video switching and display systems.

The Roadway subsystem functions are implemented with equipment typically found in the field; e.g. ramp metering equipment, vehicle detectors (e.g., inductive loop, radar, video), highway advisory radio, variable message signs, and video cameras.

Wireline Communications includes the equipment necessary for the various subsystems of the architecture, including the Traffic Management and Roadway subsystems, to exchange data to perform their transportation functions. These communications services may be provided by agency-owned communications plants (e.g. twisted pair, coaxial, fiber, or spread-spectrum radio), or may be leased from a communications service provider. It should be noted that the term " wireline communication" as used in the National ITS Architecture, refers to communication between stationary points, (e.g. traffic signal control central and field equipment). In this context, wireline communication may include wireless communication.

The Traffic Management and Roadway subsystems also provide other functions not typically associated with either freeway management systems or incident management. These include the following transportation system functions:

Traffic Signal Control Systems

- Area-wide signal coordination
- Arterial network traffic conditions
- A range of adaptive control strategies
- Integration with freeway management, incident and emergency management, transit management, etc.

Railroad Grade Crossing Systems

- Improve and automate Highway-Railroad Intersection warnings and Traffic signal control
- Provide advance warning of closures
- Coordinate traffic signal control with rail movements.

An important concept to understand from the physical architecture is that of support for combining subsystems together (or functionality from multiple subsystems) in an actual implementation. This is particularly important for the "center" subsystems, which should not be immediately thought of as separate buildings. In simplest terms, the center subsystems are not "brick and mortar." Each subsystem is a cohesive set of functional definitions with required interfaces to other subsystems; subsystems are functionally defined, not physically defined. A regional implementation may include a single physical center that collocates and integrates the capabilities from several of the center subsystems. For instance, a single Transportation Management Center may include Traffic Management Subsystem, Transit Management Subsystem, Emergency Management Subsystem, and Information Service Provider subsystem capabilities. Conversely, a single subsystem may be replicated in many different physical centers in a complex metropolitan area system. For instance, the traffic management subsystem may be implemented in a traffic management center for freeway control in addition to several distinct city traffic management centers that cooperatively control the arterials. Figure 2.4-6 provides an indication of the range of ways that center subsystems may be implemented in physical centers.

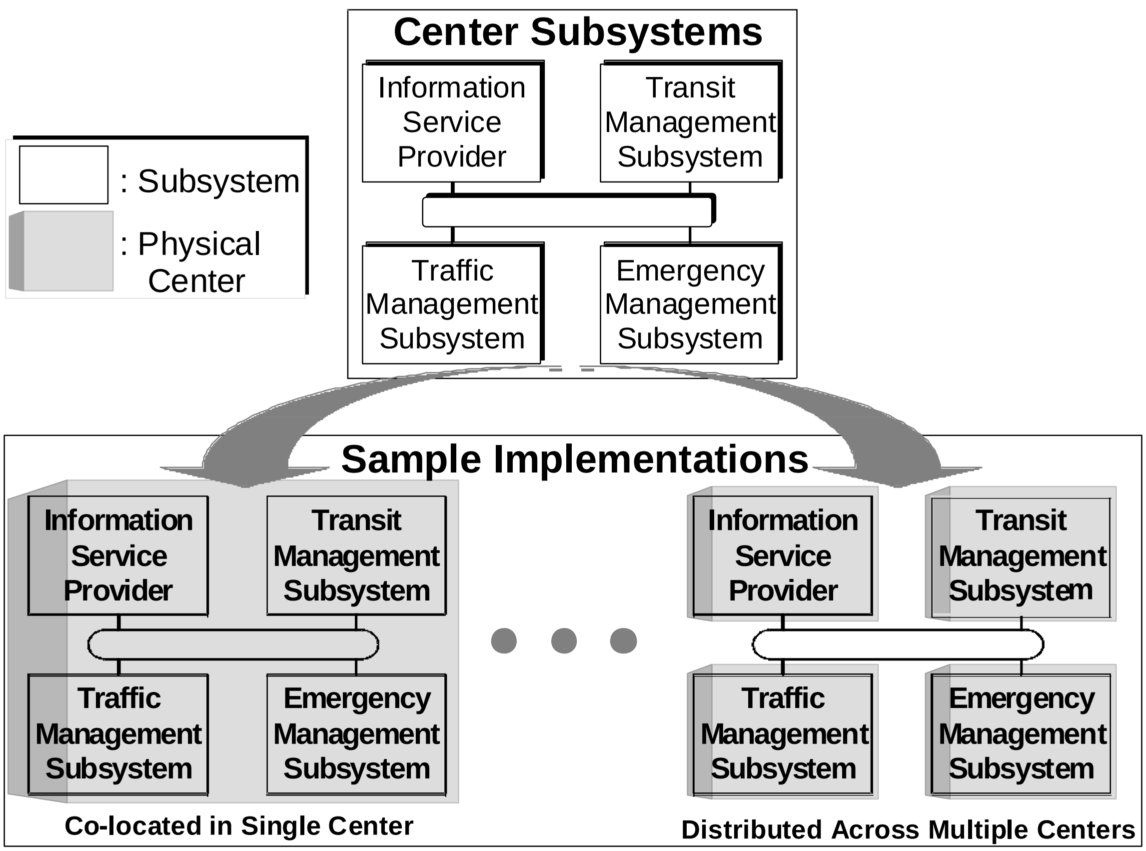


Figure 2.4-6. Center Subsystems May Be Implemented In Various Regional Configurations
(Source: National ITS Architecture Implementation Strategy)

2.4.4 Equipment Packages

The logical and physical architectures contain all of the essential architecture elements needed to provide the user services (and their more detailed requirements). Although the formal definition of the National ITS Architecture stops there, other categorizations of the architecture elements were made for the purposes of evaluation and to better understand the deployment implications. Sections 2.4.4 and 2.4.5 discuss the alternative views gained by grouping sets of key functionality together. These perspectives, which are grounded in (or tied back to) the formal definition, can be used as additional entry points into the National ITS Architecture.

The term "*equipment package*" was used in the National ITS Architecture development effort to group like functions (P-specs) of a particular subsystem together into an "implementable" package of hardware and software capabilities. The grouping of functions also took into account the user services and the need to accommodate various levels of functionality within them. The equipment packages are associated closely with market packages (which will be discussed next) and were used as a basis for estimating deployment costs (as part of the evaluation that was performed). The specific set of equipment packages defined is merely illustrative and is does not represent the only way to combine the functions within a subsystem. The National ITS Architecture has defined approximately 110 equipment packages in total; only a small portion of these are relevant to freeway or incident management.

An example of an equipment package that is relevant to incident management is "TMC Incident Detection," which is comprised of 7 process specifications, as shown below.

TMC Incident Detection Equipment Package (part of the Traffic Management Subsystem):

This Equipment package provides the capability to traffic managers to detect and verify incident. This capability includes analyzing and reducing the collected data from traffic surveillance equipment, including predicted incidents and hazardous conditions.

This equipment package consists of the following P-specs:

1.3.1.1-Analyze Traffic Data for Incidents

1.3.1.2-Maintain Static Data for Incident Management

1.3.2.1-Store Possible Incident Data

1.3.2.2-Review and Classify Possible Incidents

1.3.2.3-Review and Classify Predicted Incidents

1.3.2.4-Provide Predicted Incidents Store Interface

1.3.2.5-Provide Current Incidents Store Interface

2.4.5 Market Packages

Some of the 30 user services are too broad in scope to be convenient in planning actual deployments. Additionally, they often don't translate easily into existing institutional environments and don't distinguish between major levels of functionality. In order to address these concerns (in the context of providing a more meaningful evaluation), a finer grained set of deployment-oriented ITS service building blocks were defined from the original user services. These are called " *market packages*" in the documentation.

Market packages are defined by sets of equipment packages required to work together (typically across different subsystems) to deliver a given transportation service and the major architecture flows between them and other important external systems. *In other words, they identify the pieces of the National ITS Architecture required to implement a service*. As such, they are directly grounded in the definition of the

Architecture. Most market packages are made up of equipment packages in two or more subsystems. Market packages are designed to address specific transportation problems and needs and can be related back to the 30 user services (reference Table 2.3-2 in the Implementation Strategy document) and their more detailed requirements.

For example, the functionality of the user service named "incident management" was broken up into several market packages to allow for explicit consideration of:

- basic functions (represented by the "incident management system" marketing package), and
- institutional setting, by separating control functions typically performed by different agencies into the market packages that provide for coordination of incident management strategies across jurisdictions or agencies. For example, the "virtual TMC and smart probe data" takes into account the rural setting, where a TMC may not exist, yet coordination of incident management activities is very important. Similarly, the commercial vehicle operations "HAZMAT management" market package will enhance incident management efforts in the event of a HAZMAT spill.

Figure 2.4-7 provides an example of a marketing package related to freeway management and Figure 2.4-8 explains the basic elements of the market package diagrams.

Freeway Control (ATMS4)

This market package provides the communications and roadside equipment to support ramp control, lane controls, and interchange control for freeways. Coordination and integration of ramp meters are included as part of this market package. This package is consistent with typical urban traffic freeway control systems.

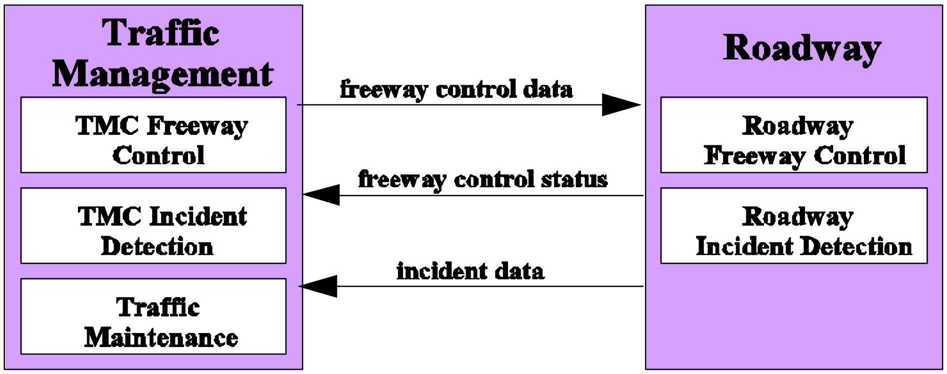


Figure 2.4-7. Freeway Control Market Package (Adapted From Appendix A of the Implementation Strategy)

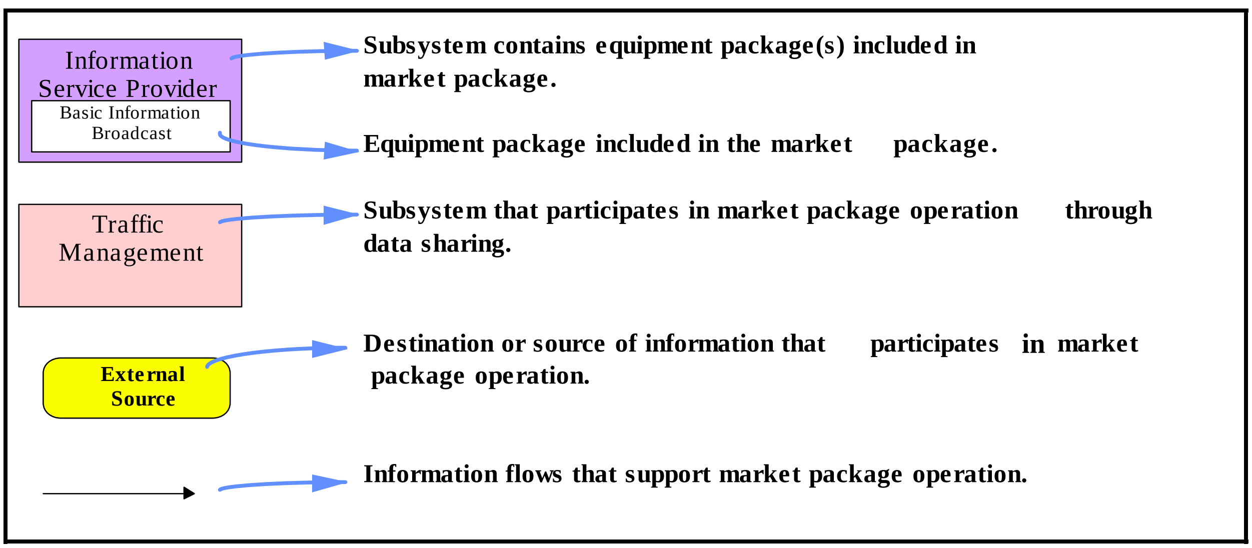


Figure 2.4-8. Market Package Elements (Adapted From Appendix A of the Implementation Strategy)

The National ITS Architecture development effort identified a total of 56 market packages that reflect the current definition of ITS and the evolving technology market. Table 2.4-4 contains a complete listing of these, grouped according to their respective major application areas. As with equipment packages, the specific set of market packages defined is merely illustrative and does not represent the only way to combine the functions and equipment in order to provide ITS services. The market packages most closely related to freeway management or incident management are highlighted in the table.

A given market package may provide only part of the functionality of a user service (supporting multiple service levels), but often serves as a building block by allowing more advanced packages to use its components. Market packages also allow early deployments to be separated from higher risk services and can specifically address varied regional needs. Because they were evaluated during the development process, supporting benefits and costs analyses were conducted for the market packages which can also be accessed as a resource.

Market packages are not intended to be tied to specific technologies, but of course depend on the current technology and product market in order to be actually implemented. As transportation needs evolve, technology advances, and new devices are developed, market packages may change and new market packages may be defined.

In short, market packages provide another method for entering into the National ITS Architecture information and can be used as an alternative starting point for defining project functional requirements and system specifications. The important point to remember is that they provide a set of manageable, service-oriented views, which allow the user to jump right into the physical architecture definition.

Table 2.4-4. ITS Market Packages

Traffic Management	**Advanced Vehicles**
Network Surveillance	Vehicle Safety Monitoring
Probe Surveillance	Driver Safety Monitoring
Surface Street Control	Longitudinal Safety Warning
Freeway Control	Lateral Safety Warning
HOV and Reversible Lane Management	Intersection Safety Warning
Traffic Information Dissemination	Pre-Crash Restraint Deployment
Regional Traffic Control	Driver Visibility Improvement
Incident Management System	Advanced Vehicle Longitudinal Control
Traffic Network Performance Evaluation	Advanced Vehicle Lateral Control
Dynamic Toll/Parking Fee Management	Intersection Collision Avoidance
Emissions and Environmental Hazards Sensing	Automated Highway System
Virtual TMC and Smart Probe Data	
Standard Railroad Grade Crossing	**Commercial Vehicles**
Advanced Railroad Grade Crossing	Fleet Administration
Railroad Operations Coordination	Freight Administration

Transit Management

Transit Vehicle Tracking

Transit Fixed-Route Operations
Demand Response Transit Operations
Transit Passenger and Fare Management
Transit Security
Transit Maintenance
Multi-modal Coordination

Traveler Information
Broadcast Traveler Information
Interactive Traveler Information
Autonomous Route Guidance
Dynamic Route Guidance
Information Service Provider (ISP) Based Route Guidance
Integrated Transportation Management/Route Guidance
Yellow Pages and Reservation
Dynamic Ridesharing
In-Vehicle Signing

Electronic Clearance
Commercial Vehicle Administrative Processes
International Border Electronic Clearance
Weigh-In-Motion
Roadside CVO Safety

On-board CVO Safety

CVO Fleet Maintenance
HAZMAT Management

Emergency Management
Emergency Response
Emergency Routing
MAYDAY Support

ITS Planning
ITS Planning

2.4.6 National ITS Architecture Documents

In summary, the National ITS Architecture provides a common structure for the design of ITS. It defines the functions that must be performed by components or subsystems, where these functions reside (e.g., roadside, traffic management center, or in-vehicle), the interfaces and information flows between subsystems, and the communications requirements for the information flows (e.g., wireline or wireless) in order to address the underlying user service requirements. Since the National ITS Architecture is also the foundation for much of the ongoing ITS standards work, consideration of the interface and information exchange requirements established by the Architecture today will likely facilitate or ease the transition to incorporating standards-compliant interfaces in the future (when approved standards are available).

The following are brief descriptions of the documents produced under the National ITS Architecture Development Program that are referred to in subsequent sections. Paper copies of these can be obtained and used as reference documents. Another way to access them is via CD-ROM or on the Internet (see Section 5.1 of this document for information on how to obtain the paper copies, the CD-ROM, and the

Internet addresses). The CD-ROM and the Internet sites will be more useful than hard copies when trying to access information rapidly. On the Internet, logical links (called "hyperlinks") between different parts of the architecture facilitate use of information for the type of exercises described later in this section. The CD-ROM also contains the underlying relational databases which define the Architecture (developed with Microsoft Access™), which can be useful for performing tailored searches or other advanced analyses. *It is important to remember that the key concepts and elements of the National ITS Architecture as presented in Sections 2.4.1-2.4.5 are interrelated and traceable in a variety of ways (forwards and backwards).*

Although the documentation at first can appear to be extensive, even overwhelming, keep in mind that only a portion of the information will apply to the specific needs of an agency at any point in time. Using the electronic tools with search capabilities and the linked HTML version of the National ITS Architecture, finding the relevant information becomes even more manageable.

US DOT plans to update and maintain the National ITS Architecture over time to reflect changing needs and correct any deficiencies that may be found through the experience of users. Accordingly, critical portions of these documents, particularly those containing the Architecture definition, will be updated over time (e.g., an update is planned for 1998). *Therefore, while this document provides specific information and examples from the National ITS Architecture (January 1997 version) for illustration purposes, the reader should always consult and defer to the latest version of the National ITS Architecture.* See Section 5 for more information on how to access the National ITS Architecture.

It is important to keep in mind that several of the documents that were produced were done for the purposes of evaluation; these documents can be used as additional resources (e.g., the Cost Analysis) but are peripheral to the fundamental definition. A first time interested reader should find the Executive Summary, Vision, and Implementation Strategy to be the most accessible starting points for looking into the documentation. A complete listing of the documents can be found in Appendix D.

<u>Vision</u>

The vision is the starting point for developing an architecture and is the component that drives everything else. The vision statement provides a description of the likely transportation system in the next 5, 10, and 20 years based on the National ITS Architecture. In the vision, the ITS User Services that the transportation system is to provide are identified in groups.

Mission

The Mission addresses the goals and objectives of a national intelligent transportation system. In the Mission, user service requirements are defined, and benefits that the system is expected to provide are identified. The mission definition ties the National ITS Architecture to the National ITS Program Plan developed jointly by US DOT and ITS America.

Logical Architecture

The Logical Architecture document contains three volumes: *Description* (Volume 1), *Process Specifications* (Volume 2), and *Data Dictionary* (Volume 3). These documents present a functional view of the ITS user services, contain diagrams that show processes and data flows among them, and define data elements, respectively.

Physical Architecture

The Physical Architecture document contains architecture flow diagrams that show data passing among physical subsystems, and presents characteristics and constraints on the data flows.

Traceability

The Traceability document shows how the National ITS Architecture satisfies the user service requirements. It contains tables that provide traceability of ITS user service requirements to National ITS Architecture elements, and traceability between logical architecture elements and physical architecture elements.

Theory Of Operations

This document provides a detailed narrative of how the architecture supports the ITS user services, described in the Mission Definition. It is a technical document, intended for engineers, operators, and others involved in detailed systems design.

Communications

The Communications document presents an analysis of the communications aspects of the National ITS Architecture. It presents a technology assessment that covers several potential communications technology alternatives. The alternatives are compared against ITS requirements. This document proposes quantitative data loading requirements for a hypothetical system design, and contains an extensive set of appendices that deal with a specific communications study.

Cost Analysis

The Cost Analysis provides typical unit costs for market packages and equipment packages. Methodologies are delineated.

Performance and Benefits Study

The Performance and Benefits Study documents the results of evaluations of several hypothetical ITS deployment scenarios. It also presents a discussion of the overall benefits of developing the National ITS Architecture.

Standards Requirements

The Standards Requirements document contains detailed information on requirements for 12 high-priority standards packages. Standards interface packages that apply directly to freeway management or incident management include:

- Emergency Management Center to Other Centers
- Dedicated Short Range Communications
- Information service provider
- Personal, transit, and HAZMAT Maydays
- Traffic Management Center for Other Centers
- Traffic Management Center for Roadside Devices
- Digital map data exchange and location referencing
- Highway-Rail Intersections
- Signal priority for emergency and transit vehicles

Implementation Strategy

The Implementation Strategy document presents a process for implementing ITS services in a phased approach. The process is part of an overall strategy that includes recommendations for future research and development, operational tests, standards activities, and training.

The Implementation Strategy translates the National ITS Architecture to implementation through market packages. It identifies the market packages that provide certain ITS services and recommends a phased deployment of those market packages to provide the most needed and most feasible user services initially, and less needed/feasible user services at a later date. The Implementation Strategy considers several items and issues regarding deployment, such as legacy systems, politics, funding, market package synergy, technology requirements, and standards requirements.

2.5 Using the National ITS Architecture to Develop Freeway and Incident Management System Projects

This section describes the specific ways that the National ITS Architecture can be used in each of the general steps of the project development process presented in Section 2.3, making use of the key concepts described in Section 2.4. This process addresses (1) needs or problem identification, (2) solution identification, (3) solution planning and design, and (4) funding, procurement, and implementation. Before discussing the specific ways it can be applied to the project development process, some additional context and general guidance is provided below.

National ITS Architecture Application Guidance

The National ITS Architecture tools are intended to augment and support existing ITS project development processes, and should be applied with engineering judgment in that context. The National Architecture is not a process in and of itself. It contributes information and analysis to existing processes (e.g., systems engineering). By providing a source for critical information early in the development process, the National ITS Architecture can lower project risks and costs while also improving the potential that the resulting deployment will have long term utility and support regional ITS integration over time.

The National ITS Architecture tools are most applicable in the early stages of project development. They fully support the rapid definition of a starting point for project definition, with local requirements then driving the tailoring of that project for specific applications. Of course, the tools do not contain all the information necessary to fully design and implement ITS projects. While helpful information is sometimes available within the documentation (for example, in the evaluation documents), specification of issues such as performance requirements, design options, technology choices, existing system interfaces and constraints, detailed implementation and operational decisions, and which standards to use needs to be carried out at the local level. Awareness of how far into the project development process the National ITS Architecture tools apply is important to being able to make the best use of them.

The National ITS Architecture can be used to provide project developers with additional options to consider for information exchanges and functionality that may not have initially been conceived at the outset of the project. As such, its utility is likely to be greater for larger projects with a variety of possible interfaces. Using the National ITS Architecture should not be viewed as an all-or-nothing requirement; rather, the material can be used as is, tailored, or dropped, as appropriate for the situation. This will be discussed further in this section.

There are several ways to apply the National ITS Architecture; the most accessible of these methods will be presented in this section. *See Section 5 for more information on how to gain access to the various formats of the National ITS Architecture (including web sites).*

Entry Points into the National ITS Architecture

The definition of the National ITS Architecture can be found in the logical and physical architectures. These architecture definitions exist in several formats, including paper documents, Microsoft Access ™ relational databases, and a HyperText Mark-up Language (HTML) model, which provides access through a linked model. The databases and the linked HTML model are available on CD-ROM and the World Wide Web. The logical and physical architecture definitions represent a breadth and depth of information that can seem overwhelming to access and apply. However, there are tools to view the architecture definition that make the extraction of information more efficient. These maps and tables provide access or "entry points" to the details of the architecture in an organized fashion. Figure 2.5-1 shows the top-level of information shown for the linked HTML model, which provides easy access to most of these entry points. Some of the key entry points and their relevance to project development are discussed in figure 2.5-1:

ITS Architecture Browsing Site

January 1997 Edition

This presentation of the National Intelligent Transportation Systems (ITS) Architecture Definition provides a hypertext view of the logical architecture, physical architecture, and implementation-oriented components of the architecture definition. This hypertext view provides access to all process specifications, data flows, subsystems, equipment packages, and terminators that make up the architecture definition. Your entry to the architecture may be through a number of different paths.

The National ITS Architecture was developed to support intelligent transportation systems extending to the year 2012. The architecture Vision provides a general forecast of the ways in which transportation improvements will be made over the next 20 years.

The architecture framework that supports this vision is made up of many physical entities (Subsystems and Terminators). By selecting a physical entity (either a subsystem or a terminator), you can browse through the process specifications that define each subsystem' s functionality or the data flows that connect the subsystems.

Near term plans and planned deployments include the Intelligent Transportation Infrastructure and CVISN. The architecture structure for these near term deployments is provided in ITI and CVISN.

Another entry which is suitable for locally searching for data flows with particular text is a complete file of Logical Architecture Data Flows (Note - this file is very big (200k bytes)) or Physical Architecture Data Flows.

Yet another entry through the logical architecture is through the Pspec (Process specification) names.

Finally, a set of standards requirements packages has been created which bundle the dataflows into sets of interest to standards organizations. The launch point for these packages is : Standards Requirements packages (Cross references are provided for flows which reside in more than one package).

The entire set of architecture documents are available on the ITS America Web Site .

Figure 2.5-1. National ITS Architecture Hypertext View

Note to the reader: As the National ITS Architecture is updated and maintained over time, changes may be made to facilitate access to key information and allow greater flexibility for the user. Thus, some of the specifics shown in Figure 2.5-1 and the mechanics discussed in subsequent text boxes for accessing the entry points may become dated. For example, in future releases, it is likely that market packages will be given greater visibility at the top page level of the HTML model.

, *User Services* are what drove the definition of the National ITS Architecture. They represent high-level descriptions of the services to be provided by ITS, from the perspective of the user. The National ITS Program Plan provides detailed descriptions of the user services. User services can be related to general needs and higher-level goals and objectives. Traceability exists to map user services to the underlying architecture definition.

, *User Service Requirements*, as previously described in section 2.4.1, are the "shall" statements that define the user services in detail and serve as the fundamental requirements of the National ITS Architecture. By selecting those user service requirements that apply to the definition of a specific system, traces can be made to the physical and logical architectures. The user service requirements are listed in Appendix A of the Traceability document on paper or CD-ROM.

, *Logical Architecture* describes " what" the National ITS Architecture must do to satisfy the User Services by defining required functions and dataflows. These functions and dataflows define the lower level details of the architecture. This tool is useful when defining the functions required to satisfy a service, requirement, or need. It leverages the extensive analysis already performed in the development of the National ITS Architecture. It provides process specifications that can be tailored to fit local requirements. The logical architecture is available on paper, CDROM, and the hyperlinked HTML model.

In the HTML model, click on "hypertext view" from the top page, then "Process Specifications" (see figure 2.5-1) in order to see a list of the p-specs, which are organized numerically according to their definition in the data flow diagram hierarchy. Or, you can click on "Logical Architecture Data Flows" in order to see the alphabetized list of logical data flows and get more information on them.

, *Physical Architecture Elements* are the subsystems and architecture flows that result from a partitioning of the logical architecture. These subsystems and architecture flows define a higher level of the architecture and can be aligned with high-level system functions such as "traffic management" or "information service provider". In this manner, a mapping at the physical architecture subsystem level can be developed that provides the links to the underlying logical architecture. The physical architecture is available on paper, CDROM, and the linked HTML model.

In the HTML model, click on "hypertext view" from the top page, then "Subsystems and Terminators" (see figure 2.5-1) in order to see a list of the subsystems, which are given alphabetically. Clicking on one of the subsystems gives lots of information about the subsystem, including a description, list of equipment packages it contains, corresponding process specifications, and an architecture flow diagram. Some of these can be further explored via additional links. You can also click on Physical Architecture Data Flows, as shown on figure 2.5-1.

- *Market Packages*, as previously described in section 2.4.5, represent slices of the architecture that address specific services such as surface street control. These physical architecture subsets can be selected and aggregated to form a high-level architecture at the subsystem level. The market packages can be traced further to equipment packages and logical architecture functions. The market package definitions are available in the Implementation Strategy on paper and the CD-ROM, and also in the hyperlinked HTML model.

> In the HTML model, click on "hypertext view" from the top page, then "ITI and CVISN" (see figure 2.5-1) in order to see a list of the market packages, which are organized into early, additional, and advanced categories. Clicking on one of the market packages produces a wealth of information on relevant subsystems, equipment packages, architecture flows, related market packages, and evaluation information.

- *ITS Infrastructure Elements* are described in US DOT's Operation Timesaver initiative and define metropolitan, rural, and commercial vehicle infrastructure elements that form the foundation of ITS. These elements represent high-level service categories (e.g., traffic signal control systems, freeway management systems, transit management systems, multi-modal traveler information systems) that are mapped into the architecture. This mapping provides the supporting architecture for the ITS Infrastructure in terms of the logical and physical architecture.

> Using the linked HTML model, a physical architecture flow diagram will be presented when one of the ITS Infrastructure elements is clicked on (click on "hypertext view" from the top page, then "ITI and CVISN" in order to see the ITS Infrastructure elements).

By using the CD-ROM with appropriate viewing software that can read ".pdf" files (such as the Adobe Acrobat® Reader), searches can be carried out on words of interest that might apply to a specific project or functional area. In addition, textual information can be copied (using the "select text" feature of the software) and pasted into a word processing application for further modification. Graphics information can also be downloaded (using "select graphics"), although it may not be as easy to modify these electronic tables or figures. Text and graphics information can always be printed and the information manually entered as inputs to other software programs.

2.5.1 Identification of Needs or Problems

As discussed in Section 2.3.1, most transportation needs and problems are identified through the planning process as part of the ongoing process of improving transportation systems at the local level. As such, the National ITS Architecture is unlikely to contribute much information to this initial step. However, it can assist agencies in identifying ITS goals and objectives that are specific to their needs. Both current and future needs should be identified. Goals and objectives identified in the National ITS Architecture (Mission Definition) that pertain to freeway management systems include:

- Increase operational efficiency and capacity of the transportation system
    - Increase operational efficiency
    - Increase speeds and reduce stops
    - Reduce delays at intermodal transfer points
    - Reduce operating costs of the infrastructure
    - Increase private vehicle occupancy and transit usage
    - Reduce private vehicle and transit operating costs
    - Reduce freight operating costs and increase freight throughput
    - Decrease cost of freight movement to shippers, including:
        - More reliable “just-in-time” delivery
        - Travel time and cost
        - Driver fatigue and stress
        - Safety (e.g., from tracking hazardous material)
- Enhance personal mobility and the convenience and comfort of the transportation system
    - Increase personal travel opportunities
    - Decrease personal costs of travel including:
        - Comfort, stress, fatigue, and confusion
        - Safety and personal security
    - Increase sense of control over one’s own life from predictable system operation
- Improve the safety of the nation’s transportation system
    - Reduce number and severity (cost) of accidents and vehicle thefts
    - Reduce fatalities
- Reduce energy consumption and environmental costs

- Reduce vehicle emissions and fuel consumption due to congestion
- Reduce noise pollution
- Reduce neighborhood traffic intrusiveness

- Enhance present and future economic productivity of individuals, organizations, and the economy as a whole
  - Increase sharing of incident/congestion information
  - Reduce information-gathering costs
  - Increase coordination/integration of network operation, management, and investment

The National ITS Architecture documentation includes a Vision Statement, which describes ITS capabilities now and into the future in magazine article style. The Vision can also serve to foster general ideas about the types of local needs and problems that ITS can be used to address.

The National ITS Architecture also includes data collection subsystems, such as the planning subsystem, to highlight the value of using ITS to collect long-term performance data on the transportation system. Collecting and using this type of information can enhance and augment the process of identifying needs and problems in the future.

Useful National ITS Architecture Documents: Mission Definition, Vision Statement

2.5.2 Identification of Solutions

There are at least two major ways that the National ITS Architecture can be applied to the identification of alternative solutions to the given needs and problems, leading to the ultimate selection of a preferred solution. During this step, traditional solutions to the problem or combinations of traditional and ITS strategies may also be explored.

2.5.2.1 User Services

As discussed in Section 2.4.1, user services and associated user service requirements were fundamental to the National ITS Architecture development effort. These user services were designed to address surface transportation needs. Agencies may wish to review the list of user services in their search for potential solutions to the given needs and problems. A list of user services and those most relevant to freeway and incident management systems was provided in Table 2.4-1.

The following is a summary of the user service requirements most pertinent to freeway management and incident management functions:

The traffic control user service is designed to:

- Optimize traffic flow
- Provide traffic surveillance
- Provide ramp metering
- Provide the ability to give priority to certain types of vehicles
- Provide device control capabilities
- Provide information to other functions

The incident management user service is designed to:

- Identify scheduled/planned incidents (e.g., construction activity)
- Detect incidents
- Formulate response actions
- Support coordinated implementation of response actions
- Support initialization of response actions
- Predict hazardous conditions

Under this approach for this step, agencies should select those user services and user service requirements that are most relevant toward meeting the current and future needs previously identified. Those user services and user service requirements that remain in the preferred solution can be carried further into the next step of project development.

2.5.2.2 Market Packages

Reviewing and selecting market packages is another convenient approach that can be taken for performing this step. As discussed in Section 2.4.5, market packages were defined in the National ITS Architecture development effort to serve as deployment-oriented ITS service "building blocks." In general, the market packages offer a finer grained set of options than do user services, offering more alternatives to choose from in this step of the process. In addition, evaluation information (such as costs and benefits related material) is more readily available for the market packages than for user services, which can provide added support to project planning. As shown in Table 2.4-4, the market packages identified in the National ITS Architecture that support freeway management and incident management functions include:

- *Network Surveillance* – This market package provides the fixed roadside surveillance elements that use a communications system to transmit surveillance data. It can be completely local, such as loop detection connected with signal control, or it can be CCTVs sending back images to traffic management centers. Surveillance enables traffic managers to monitor road conditions, identify and verify incidents, analyze and reduce the collected data, and make that data available to users and private information providers.

- *Probe Surveillance* – This is an alternative surveillance approach in which the travel times of individual vehicles are tracked. Two general communications paths are possible: (1) wide-area wireless communications between the vehicle and a traveler information service provider can be used to transmit current vehicle location and status, and (2) a dedicated short range communications link between the vehicle and roadside can be used to provide equivalent information back to a traffic management system.

- *Surface Street Control*– This market package provides the communications links and the signal control equipment for completely local surface street control and/or arterial traffic management control. It provides for coordination between systems controlled by different jurisdictions.

, *Freeway Control* – This market package provides the communications and roadside equipment to support ramp control, lane control, and interchange control for freeways. Coordination and integration of ramp meters are included as part of this market package.

, *Regional Traffic Control* – This market package advances the surface street control and freeway control market packages by allowing integrated inter-jurisdictional traffic control. This market package provides for the sharing of traffic information and control among traffic management centers to support a regional control strategy.

, *Incident Management* – This coordinates both predicted and unexpected incidents so that the impact to the transportation network and traveler safety is minimized. Requisite incident detection capabilities are included in the freeway control market package and through regional coordination with other traffic management and emergency management centers.

, *Traffic Information Dissemination* – This market package allows traffic information to be disseminated using roadway equipment, such as changeable message signs, or highway advisory radio. The emphasis is on provision of basic traffic information or other advisories by means that require minimal or no in-vehicle equipment to receive the information. This package provides a tool that can be used to notify drivers of incidents. Careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information.

, *Traffic Network Performance Evaluation* – This market package includes advanced algorithms, processing, and mass storage capabilities that support historical evaluation, real-time assessment, and forecasts of traffic network performance. This includes the prediction of travel demand patterns to support better link travel time estimation for route planning purposes.

Ë *HOV and Reversible Lane Management* – This provides for management of HOV lanes by coordinating freeway ramp meters and connector signals with HOV lane usage signals. Preferential treatments are given to HOV lanes. Vehicle occupancy detectors may be installed to determine if vehicles are HOVs. It also provides the capability for traffic managers to access and manage reversible lane facilities. It includes the hardware and software to electronically reconfigure intersections to manage dynamic demand changes and special events.

Ë *Virtual TMC and Smart Probe Data* – This market package provides for the special requirements of a rural road system. Instead of a central TMC, the traffic management is distributed over a very wide area (e.g., a whole state or collection of states). Each locality has the capability of accessing available information for assessment of road conditions. The package uses vehicles as smart probes that are capable of measuring road conditions and providing this information to the roadway for relay to the Traffic Management Subsystem. Potentially, the package could directly relay information to following vehicles (i.e., the automated road signing equipment is capable of autonomous operation). In-vehicle signing is used to inform drivers of detected road conditions.

- *HAZMAT Management* – This market package integrates incident management capabilities with commercial vehicle tracking to assure effective treatment of HAZMAT material and incidents. HAZMAT tracking is performed by the Fleet and Freight Management Subsystem. The Emergency Management subsystem is notified by the Commercial Vehicle if an incident occurs and coordinates the response. The response is tailored based on information that is provided as part of the original incident notification or derived from supplemental information provided by the Fleet and Freight Management subsystem.
- *Emergency Response* – This market package automates emergency vehicle notification upon verification of the location and nature of an incident by the Emergency Management subsystem. This package uses existing and emerging wireline interconnects to sensors, and vehicle position locators for incident detection. Coordination between Emergency Management Subsystems supports emergency notification and coordinated response between agencies.

For additional help in connecting needs and problems with market packages, the Implementation Strategy document contains a table that provides this kind of information. For illustration, the excerpt of this table, shown as Table 2.5-1, shows the market packages that best address the problems of traffic congestion and air pollution.

In addition, the Performance and Benefits Study contains tables that relate the ITS system goals to individual market packages (Table 5.3-1 of the document) and the likely benefits of each market packages (multiple tables in Section 5.2 of the document). Agencies can use these as an aid in determining which market packages best address local needs.

Useful National ITS Architecture Documents: Traceability Matrix, Implementation Strategy, Performance and Benefits Study

Table 2.5-1. Connecting Problems, Solutions, and the National Architecture (Excerpt from Table 4.2-1 of the Implementation Strategy)

Problem	Solution	Conventional Approach	Advanced Systems Approach	Supporting Market Packages
Traffic Congestion	Increase roadway capacity (vehicular throughput)	· New roads · New lanes	· Advanced traffic control · Incident Management · Electronic Toll Collection · Corridor Management · Advanced vehicle systems (Reduce headway)	· Surface Street Control · Freeway Control · Incident Management System · Dynamic toll/parking fee management · Regional Traffic Control · Railroad Operations Coordination · Advanced vehicle longitudinal control · Automated highway system
	Increase passenger throughput	· HOV Lanes · Car Pooling · Fixed route transit	· Real-time ride matching · Integrate Transit and Feeder Services · Flexible route transit · New personalized public transit	· Dynamic Ridesharing · Multi-modal coordination · Demand Response Transit Operations
	Reduce demand	· Flex Time Programs	· Telecommuting · Other telesubstitutions · Transportation Pricing	· Dynamic toll/parking fee management
Air Pollution	Increase transportation system efficiency, reduce travel and fuel consumption	· More efficient conventional vehicles · Vehicle emissions inspections · Promotion of alternatives to single occupant vehicle travel · Increased capacity to reduce vehicle delay · Regulations	· Remote sensing of emissions · Advanced traffic management to smooth flows · Multi-modal pre-trip info · Telecommuting · Other telesubstitutions · Transportation Pricing · Alternative fuel vehicles	· Emissions and environmental hazards sensing · Surface Street Control · Freeway Control · Regional Traffic Control · Interactive Traveler Information · Dynamic Toll/Parking Fee Management

2.5.3 Planning and Design of the Solution

Project planning and design, particularly in the early phases, is likely the most important step for applying the National ITS Architecture information. There are a variety of ways to apply the National ITS Architecture in this step; the most important of these are discussed below. By using the various entry points described earlier in Section 2.5, other methods for facilitating the design process can be explored. The overall goal is for agencies to harness the analysis work already performed and to have the opportunity to consider additional functions, interfaces, and information sharing possibilities beyond the initial project scope, which can be planned for now in anticipation of future needs.

The planning and design activities that are discussed in this section include:

- Determine Functional Requirements
- Identify Information Exchange Requirements
- Identify Standards

2.5.3.1 Determine Functional Requirements

The National ITS Architecture can be used as an input to defining project or system functional requirements. This involves a more detailed look at the user service requirements or market packages carried through from the previous step. Potential approaches include:

- *User service requirements* – The user service requirements associated with the proposed solution can be evaluated for their applicability to the project. For example, they can be used to augment the functional specification that may be put out in an RFP for detailed design and procurement. Using the Traceability Matrix, the process specifications that are associated with the relevant (selected) user service requirements can also be analyzed. For those process specifications that are maintained in the system design, the data is available to relate those functions to the rest of the logical and physical architecture.

- *Market packages* – The high-level architecture defined using the market packages can be further refined by examining the logical architecture elements that support these subsystems and architecture flows. The linked model can provide the maps to the underlying functions and data flows of the logical architecture. The list of process specifications associated with the market packages can be tailored to satisfy more closely the local needs or requirements that the solution must address. As originally defined, the market packages may identify more subsystems, equipment packages, or terminators than are required to satisfy the identified needs. While this presents a chance to drop unneeded features, it should also be viewed as an opportunity to consider additional capabilities that may satisfy other needs at marginal cost. During the process of designing the project, expansion capability may also be identified that can be planned for in future solutions. See Section 2.5.3.4 for an example of how to aggregate and tailor market packages to meet local needs.

- *Physical Architecture Subsystems* – Even if the user service or market package approach isn't followed initially, agencies should be able to determine the relevant subsystems associated with a given project. Given a list of these subsystems, the physical architecture entry point can be used to determine the associated equipment packages, process specifications, and information flows. The underlying process specifications can be evaluated for their applicability and potential contribution to the functional needs of the given project (or future ones). This entry point is particularly useful for projects with a substantial amount of central equipment and software costs, such as a TMC upgrade.

For each alternative presented above, the National ITS Architecture material can be used as is, dropped, modified, or added to as appropriate to the situation. In most cases, additional performance requirements and other types of decisions will need to be included in the specification of a system before it can be procured (even if the detailed design work is to be put out for bid). It is important to recognize that the National ITS Architecture does not address reliability, availability, or maintainability. These and other operational and maintenance needs must be added to any requirements definition or system specification.

Unique local needs that are not covered as part of the 30 user services will also require the addition of subsystems or functions that are outside the National ITS Architecture. These types of elements may represent legacy system functions or portions of legacy systems. The addition of functionality, subsystems, and external interfaces (terminators) that are not part of the National ITS Architecture is part of the process of tailoring the solution architecture to satisfy the identified needs.

2.5.3.2 Identify Information Exchange Requirements

The physical architecture identifies the physical subsystems and data flows among subsystems that will support the communications requirements of a given project. It is important to identify physical data flows because they are the actual representation of communication ties among agencies and subsystems. Figure 2.5-2 illustrates a simplified physical architecture data flow diagram for traffic management. Appendix C contains a more detailed listing and explanation of the physical architecture flows that are relevant to freeway management and incident management functions.

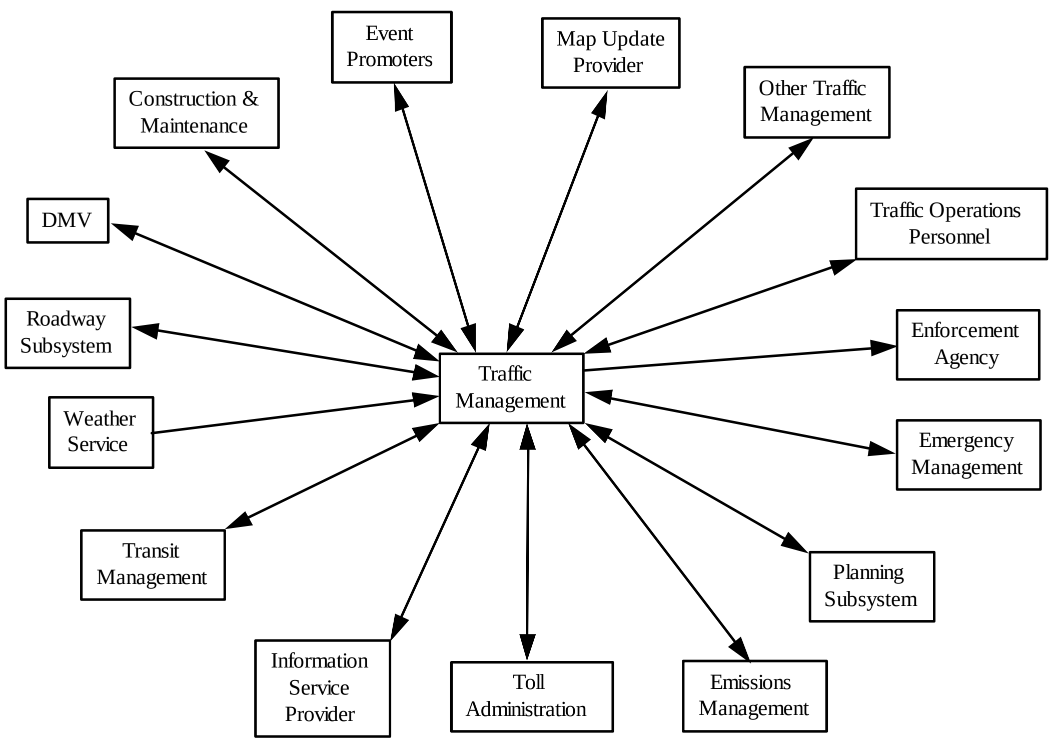


Figure 2.5-2. Example Physical Data Flows for Traffic Management

In the process of specifying the information exchange requirements for the project, the underlying logical data flows associated with the identified physical information flows should be evaluated for their inclusion in the definition of communication messages. In cases where data flows are not currently available (but might be in the future), accommodation of extra message fields in the software development for the project should be considered. This will likely be done more economically if it is carried out now instead of having to modify the software later to handle the increased and changed needs for communications.

The Theory of Operations document can be used to obtain a better understanding of how the physical architecture elements work together to provide ITS services. For example, it provides diagrams and descriptions indicating the intended sequencing of messages for particular user services. These diagrams illustrate the sharing of information between subsystems, which are relevant in determining the working relationships needed between different agencies for a given project. This type of information can be invaluable in developing a concept of operations for a project.

During the process of analyzing the possible information requirements contained in the National ITS Architecture, information exchanges beyond what was originally planned may become desirable additions to the project. This could entail establishing working relationships and agreements with agencies that were not originally part of the project planning effort, which could lead to an expansion of the project steering team. The information exchanges identified in the National ITS Architecture can stimulate the discussion of operational roles and responsibilities and are therefore critical to establishing the operations requirements for the project.

2.5.3.3 Identify Standards

The rapid pace of progress in technology will introduce many new systems and devices into transportation systems. As transportation systems incorporate advanced technology, there will be a need for standards to promote multi-vendor interoperability and ease of integration. With standards, it is simpler to share data and communicate between transportation systems, particularly between agencies within the same region. Without standards, it is more difficult to integrate transportation systems with each other, and consequently there is a danger of isolating systems and limiting their potential effectiveness in solving a region’s transportation needs and problems.

One of the major reasons for developing the National ITS Architecture was to identify where standard system interfaces were needed. Because the National ITS Architecture is serving as the common foundation for the ongoing ITS standards development work, factoring it into your current system enhancements will facilitate the transition to a standard interface definition in the future. The Standards

Requirements document contains detailed information on the requirements for 12 high-priority standards packages.

Agencies can take advantage of these standards as they emerge by specifying their use in procurement packages. Among the pertinent national ITS standards development activities in process are the suite of standards being developed under the National Transportation Communications ITS Protocol (NTCIP) effort, and Dedicated Short Range Communications (DSRC) standards. Appendix A contains sources for additional information on these and other relevant standards development activities.

Agencies should also keep in mind that a variety of existing communications and information-based standards, which may have been created for other reasons, are applicable to ITS projects and are being used in systems today.

2.5.3.4 Market Package Aggregation and Modification Illustration

To illustrate some of the concepts of Section 2.5.3, this subsection illustrates the use of market packages as a way to create a high-level physical architecture that can be further tailored to address local requirements.

As market packages are selected to address the given problems and needs, they may be aggregated by connecting or overlapping duplicate subsystems. The subsystems are connected by architecture flows that define subsystem interfaces. The aggregation of market packages will result in a high-level physical architecture that has been extracted from the National ITS Architecture and will represent a starting point for refinement and tailoring to unique local needs or requirements. For example, the Freeway Control and Incident Management System market packages might be found to be the most applicable solutions to the identified problem.

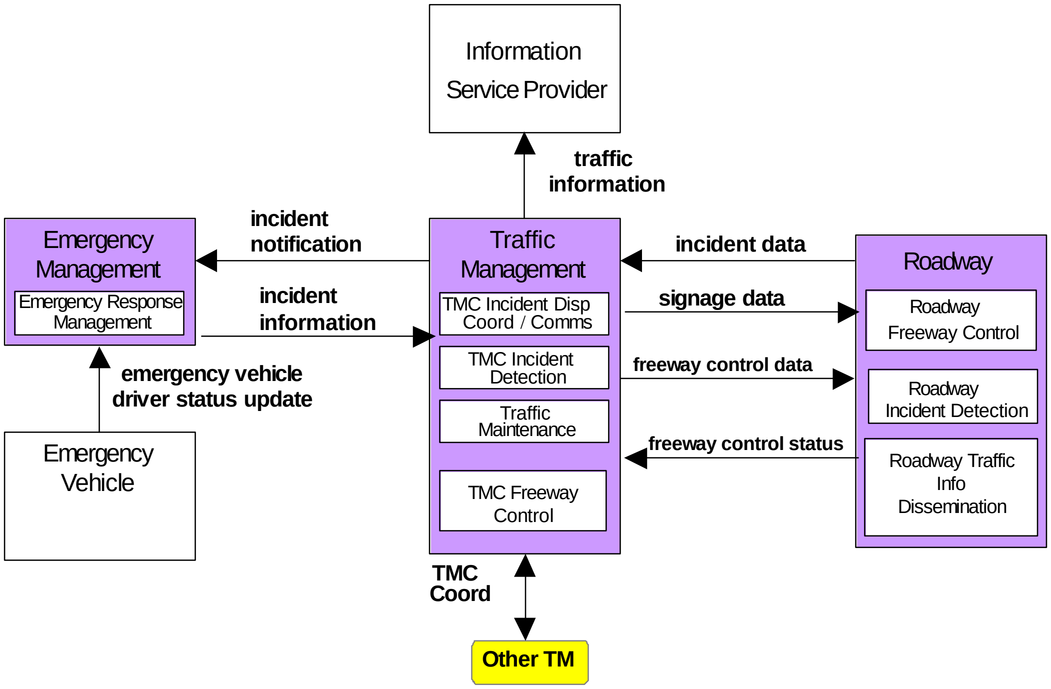


Figure 2.5-3. Aggregation of Freeway Control and Incident Management Systems

The aggregation of these two market packages would result in the architecture illustrated in Figure 2.5-3. This diagram shows the aggregation of the equipment packages (shown as white boxes inside the gray subsystems) and physical architecture flows (shown as arrows) of both market packages. Compared to the original Freeway Control market package diagram (shown as Figure 2.4-7), the traffic management subsystem has accumulated more functionality in the aggregated market package since the equipment packages from the individual market packages for that subsystem have been aggregated as well. In addition, more architecture flows have been identified between the traffic management and roadway subsystems resulting in an expanded interface definition.

The solution architecture should be analyzed to determine if it properly addresses the identified needs. The solution architecture may have more subsystems than are required or it may be missing subsystems or terminators required to satisfy the needs. If there are extraneous subsystems or architecture flows, they can be dropped from the architecture. For instance, if there was only one TMC in the area and no coordination was deemed necessary in the future, the TMC Coordination architecture flow and the ‘Other TM’ terminator would be dropped.

If a requirement is not satisfied by the architecture, subsystems and/or architecture flows should be added. The physical architecture should be reviewed for additional subsystems or terminators and their associated architecture flows to satisfy any missing elements in the solution architecture. For example, if there were an additional requirement that a Transit Management facility be given direct incident notification, a subsystem would be added to include a terminator and a ‘traffic information’ architecture flow from the Traffic Management Subsystem to exchange the information. Figure 2.5-4 illustrates this modification to the architecture.

The high-level architecture defined using the market packages and physical architecture subsystems can be further refined by examining the logical architecture elements that support these subsystems and architecture flows. The list of process specifications can be tailored to satisfy more closely the local needs or requirements that the solution must address. The solution architecture will be refined to a point where it satisfies the identified needs in sufficient detail that design specifications can be generated as inputs to the final design of the solution.

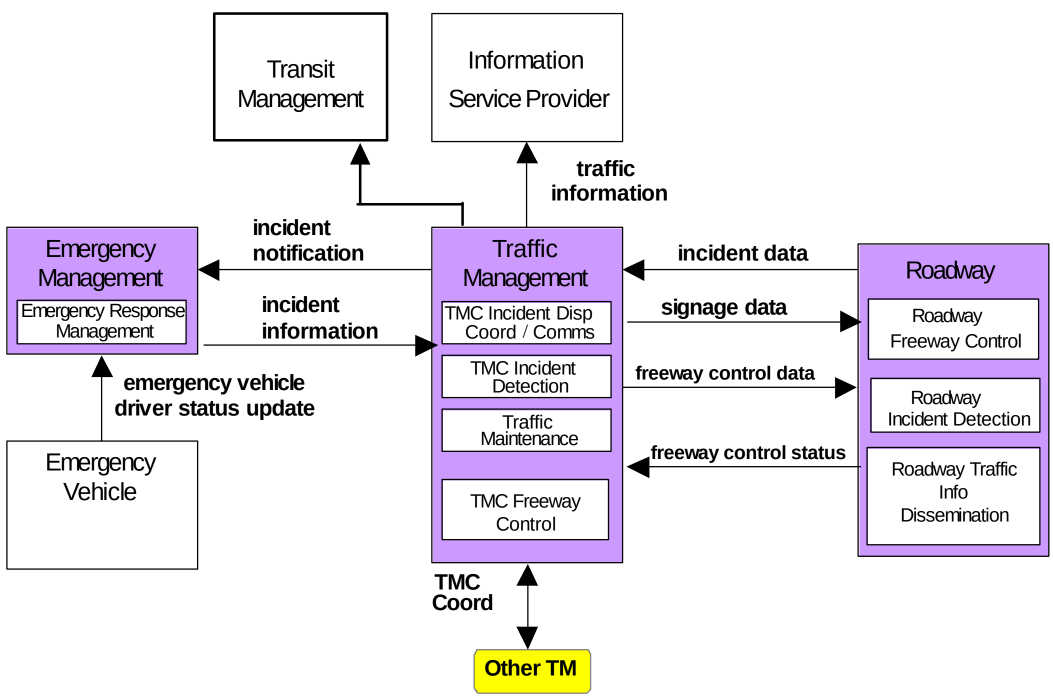


Figure 2.5-4. Modification of Aggregated Market Package Architecture

Useful National ITS Architecture Documents: Logical Architecture, Physical Architecture, Traceability, Theory of Operations, Communications Document, Standards Requirements Document

2.5.4 Funding, Procurement, and Implementation

The National ITS Architecture material is most useful in earlier steps of the system or project development process. Nevertheless, it can also provide valuable information during this final step, particularly in the area of cost estimation. The evaluation documents and the Implementation Strategy can also be used as a general resource during this final phase of project development.

Cost Estimates

As a tool to assist in the estimation of costs for planning purposes, a series of spreadsheets that contain approximate non-recurring (initial capital investments) and recurring (operation and maintenance) costs of equipment packages was developed as part of the National ITS Architecture effort. These are provided in the Cost Analysis document. These costs are provided in 1995 U.S. dollars.

These costs should be applied cautiously and should not be used as a recipe for determining the actual costs of ITS deployments, since these costs vary substantially over time and from region to region. Consequently, current prices should be collected by anyone attempting to generate a detailed cost estimate for an ITS application. However, the spreadsheets can be useful in producing first order cost estimates for planning purposes. Moreover, they can be used to determine which factors affect the cost of a particular equipment package.

Useful National ITS Architecture Documents: Physical Architecture, Implementation Strategy, Cost Analysis

2.6 Freeway and Incident Management Project Application Scenarios

This section will step through two representative freeway and incident management scenarios to help illustrate the guidance presented above on how the National ITS Architecture can be used to support the design and deployment of ITS applications for freeway and incident management systems. The two scenarios are:

- Freeway and Incident Management System Upgrade Scenario (Section 2.6.1)
- Freeway-Arterial Coordination (Section 2.6.2)

Each of the scenarios includes a brief presentation of each of the four general steps referenced throughout this section, but is tailored to illustrate different aspects of the previously presented guidance on applying the National ITS Architecture.

2.6.1 Freeway and Incident Management System Upgrade Scenario (Using Market Packages)

In this scenario, the freeway management agency in a metropolitan area wants to implement several advanced systems to enhance traffic management as well as improve response capabilities in the event of an incident.

This scenario illustrates the use and tailoring of market packages and their supporting cost analysis and highlights the consideration of standards.

This Scenario

A growing metropolitan area commissioned a Major Investment Study (MIS) of a suburban freeway corridor. The 27-mile corridor has experienced rapidly increasing congestion as a result of the continuing spread of jobs and residences away from the region's central business district (CBD). One of the recommendations of the MIS was to enhance the freeway management system to better manage traffic on this stretch of freeway. Freeway management features to be considered are surveillance (point detection and video cameras), incident management, variable message signs, and ramp metering. The State currently operates a freeway management system that encompasses several intersecting freeways primarily serving traffic destined for or departing from the CBD. As part of the new system installation, the freeway management center will upgrade its video display capabilities. The new equipment in the center will facilitate the gradual evolution of the freeway management center into a multi-modal regional transportation operations center.

The State DOT is the implementing agency, but both a policy-level Steering Committee and a technical-level Operations Committee were formed to guide development and deployment. These committees consist of representatives of agencies with transportation management responsibility in the region, including several city Public Works Departments; police, fire and emergency services agencies; transit providers; the MPO; and private traveler information service providers.

2.6.1.1 Identification of Needs or Problems

Existing System

The State DOT operates a freeway management system that monitors the main corridor and several intersecting freeways. However, surveillance capability is limited to two fixed view CCTV cameras on each of the five main freeway interchanges. Incident management capabilities, particularly with regard to communications, are limited as well. In the event of an incident, responding unit commanders are directed to report to the Incident Commander, typically equipped with a walkie-talkie to relay directions to their units. The contracted towing services do not receive incident information directly and typically are not called for until very late in the process.

Objectives

The MIS planning process established a set of goals and objectives for the corridor. The Steering and Operations committees adopted a set of project-specific goals and objectives based on these and a review of ITS goals and objectives contained in the National ITS Architecture Mission Definition document. The goals and objectives adopted were:

Goal #1 – Increase the operational efficiency of the freeway

> Objective #1 – Reduce average peak period travel times through the corridor by 15%

Goal #2 – Enhance the convenience and comfort of travel through the corridor

> Objective #1 – Reduce occurrences of freeway delays of over 15-minutes by 50%
>
> Objective #2 – Inform incident response agencies (police, fire, emergency services, towing) and traveler information service providers of freeway incidents within 5-minutes of their occurrence 80% of the time
>
> Objective #3 – Provide traveler information service providers with information on freeway construction activities one-week in advance 100% of the time

Goal #3 – Improve safety along the freeway

Objective #1 – Incident response times are within 15-minutes 80% of the time

Objective #2 – Average incident clearance time is reduced by 33% (to reduce probability of secondary accidents occurring)

Objective #3 – The accident rate at ramp merge points is reduced by 33%.

Objective #4 – The overall freeway accident rate is reduced by 15%.

Goal #4 – Reduce fuel consumption and emissions.

Objective #1 – Reduce estimated wasted fuel consumption by 25%.

Objective #2 – Reduce estimated hydrocarbon and carbon monoxide emissions in the corridor by 10%

Goal #5 – Enhance organization productivity

Objective #1 – Improve relationships between transportation agencies and emergency services agencies (police, fire, ambulance)

Objective #2 – Improve relationships with private traveler information service providers

Objective #3 – Improve public image of government services

Objective #4 – Provide data suitable for performance assessment purposes

2.6.1.2 Identification of Solutions

The first task of the State DOT project manager was to work with the Operations Committee in developing a functional description of the system based upon several objectives established in the MIS planning process. The project manager referred to the functional description documents for the existing freeway management systems in the region, and obtained functional description documents from several freeway management systems from around the country. The project manager also reviewed relevant parts of the National ITS Architecture Implementation Strategy document.

As a result of these reviews, and review of other relevant technical literature, it was decided that the functional description should provide for:

- Point detection every ½-mile along the freeway mainline to gather freeway volume, occupancy and speed data
- Video surveillance capability for the entire length of the freeway corridor
- A traffic responsive ramp metering system
- Variable message signs in advance of major diversion points

- New software to control and manage the regional freeway management system
- An incident detection algorithm
- Software to assist with incident response
- Database management capability for historical volume, occupancy and speed data
- Communications capability to provide for exchange of data between the regional operations center and freeway management field devices
- Communications capability to transmit video images for incident verification purposes and to share with fire and police facilities, the State-contracted towing company facilities servicing the freeways, as well as commercial television stations. This video image could enhance a towing company's ability to assess the appropriate equipment to be deployed.
- Development of a wide-area network through which emergency services agencies, other transportation management agencies and private traveler information service providers can share data
- Installation of a large rear-projection video system at the regional operations center, as well as new computer terminals, workstations, and office space

Traffic engineers from the Operations Committee have attended a recent offering of the National ITS Architecture training course and have chosen to review the list of market packages for their potential application to this project. Based on a best match of their needs with the available market packages, the **Freeway Control** (Figure 2.6-1, previously shown as Figure 2.4-7), **Network Surveillance** (Figure 2.6-2), **Traffic Information Dissemination** (Figure 2.6-3) and **Incident Management System** (Figure 2.6-4) market packages were selected for further analysis.

Freeway Control (ATMS4)

This market package provides the communications and roadside equipment to support ramp control, lane controls, and interchange control for freeways. Coordination and integration of ramp meters are included as part of this market package. This package is consistent with typical urban traffic freeway control systems.

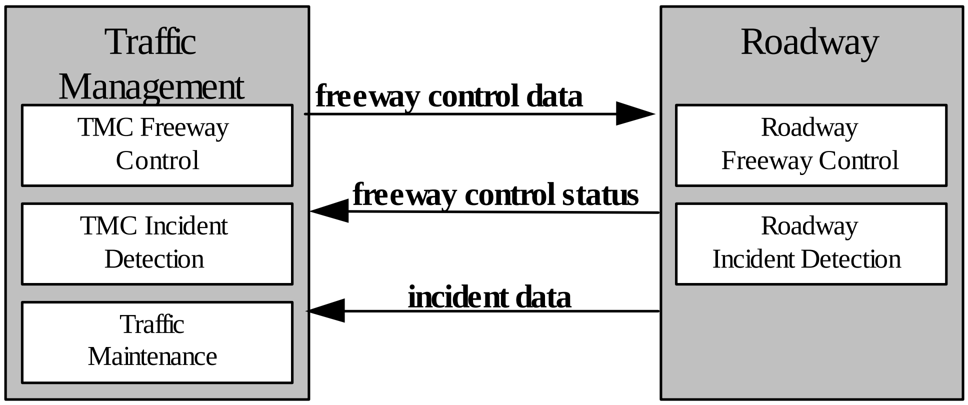


Figure 2.6-1. Freeway Control Market Package (Adapted From Appendix A of the Implementation Strategy)

Network Surveillance (ATMS1)

This basic market package provides the fixed roadside surveillance elements utilizing wireline communication to transmit the surveillance data. It can be loop detection connected with traffic signal control or it can be CCTVs sending back data to the traffic management centers. This enables traffic managers to monitor road conditions, identify and verify incidents, analyze and reduce the collected data, and make it available to users and private information providers.

Figure 2.6-2. Network Surveillance Market Package (Adapted From Appendix A of the Implementation Strategy)

Traffic Information Dissemination (ATMS6)

This market package allows traffic information to be disseminated using roadway equipment like variable message signs or highway advisory radio. The emphasis is on provision of basic traffic information or other advisories that require minimal or no in-vehicle equipment to receive the information. This package provides a tool that can be used to notify drivers of incidents; careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information.

Figure 2.6-3. Traffic Information Dissemination (Adapted From Appendix A of the Implementation Strategy)

Incident Management System (ATMS8)

This market package manages both predicted and unexpected incidents so that the impact to the transportation network and traveler safety is minimized. This market package provides traffic management center equipment that supports traffic operations personnel in developing an appropriate response in coordination with emergency management and other incident response personnel to confirmed incidents. The same equipment assists the operator by monitoring incident status as the response unfolds. The coordination can also extend to tow trucks and other field service personnnel.

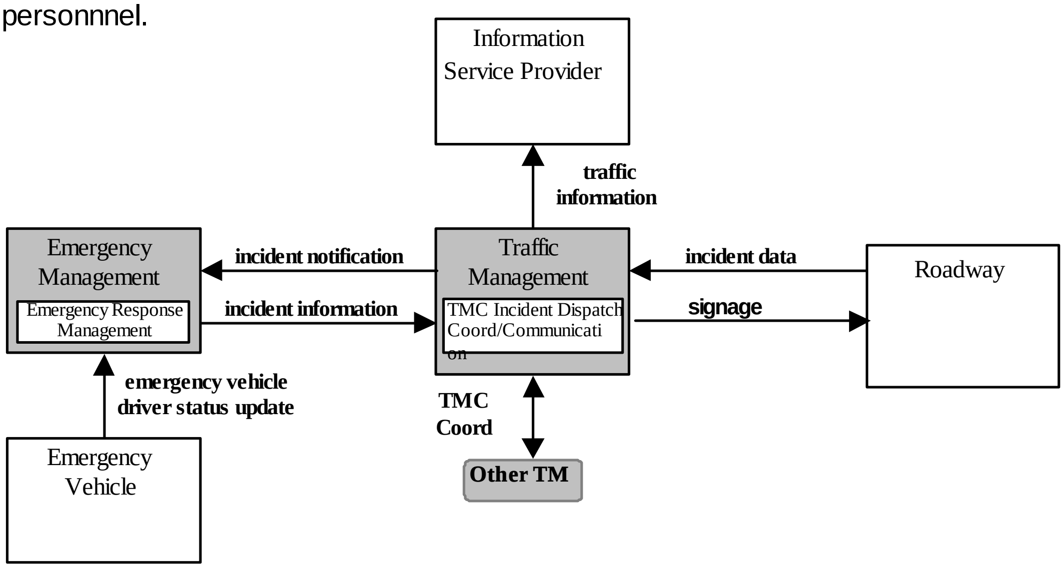


Figure 2.6-4. Incident Management System (Adapted From Appendix A of the Implementation Strategy)

2.6.1.3 Planning and Design of the Solution

At this point, the State DOT procured the services of a consulting firm, selected on the basis of its experience in the design of similar freeway management system projects.

The contract called for the development of a Functional Description document that would describe the system concepts and freeway management features identified by the Operations Committee in additional layers of detail.

The contract also called for preparation of an Operations Plan that would describe how the system features would be used to achieve the system goals and objectives.

The Operations Plan would also describe operations policies, and assert operations and maintenance personnel needs, skill levels, and annual budgets.

Finally, the contract called for preparation of system deployment procurement documents, including Plans, Specifications and Estimates (PS&Es), assistance in proposal evaluation, and assistance in reviewing the work of the successful deployment bidder.

As part of the planning and design process, the Operations Committee analyzed the market packages previously selected in order to determine the functions and information flows that need to be included between the traffic management center and incident response entities and also with field components. Doing so also allowed the State to determine if additional enhancements or modifications to the design were needed to meet local requirements. This involved a review of the functionality (P-specs) of the applicable equipment packages and the contents of the applicable physical architecture data flows (as shown in the market package diagrams). In addition, the secondary flows associated with these market packages were investigated on the linked HTML model on the Internet. The results of this process are discussed below.

Market Package Tailoring Illustration

The following tables illustrate some of the modifications made during the process of analyzing the market packages in light of the existing system configuration and future plans of the State and other transportation operating agencies within the region. The Operations Committee did not find that there were many extraneous functions and information flows in the selected market packages. In fact, several processes were added to the functional requirements of the project, and a physical data flow was added to account for the desire of the State DOT to provide a live video feed to several contracted towing facilities.

Functional Requirements Modifications (Example)

Subsystem	Equipment Package	Change	Reason
Traffic Management	TMC Freeway Control	ADD P-spec 1.1.5 (Exchange data with other Traffic Centers)	No current regional traffic operations center. However, use of this p-spec leaves hook for coordinating freeway with arterial signal controls
	Collect Traffic Surveillance	ADD P-spec 1.1.2.5 (Process Tag Data for Link Time Data)	Allows this equipment package to take in and process probe data as well as loop data and video for incident detection

Information Exchange Requirements Modifications (Example)

Subsystem: From -> To	Physical data flow	Change /Explanation
Traffic Management -> Roadway	Signage data (MODIFY)	Use existing system protocols/message conventions
Traffic Management -> Emergency Management	traffic information (ADD)	Provide live feed of video traffic information directly to contracted towing services facility

As part of the design of the project, the Operations Committee has decided to investigate the availability of standards for this implementation.

Identifying Applicable ITS Standards for Ramp Meters

There are two families of traffic signal controller/ramp metering standards currently in widespread use in the United States today: National Electrical Manufacturers Association (NEMA) and Type 170. The NEMA family includes the NEMA TS-1 and TS-2 controllers and the Type 170 includes the Model 170, Model 179, and model 2070.

The Model 170 and 179 and the NEMA controllers are heavily used throughout the nation, with the Model 2070 quickly gaining acceptance. The selection of which controller standard to use is dependent on the capabilities and functions needed.

National Transportation Communications for ITS Protocol (NTCIP)

The National Transportation Communications for ITS Protocol (NTCIP), one of the standards efforts being developed in coordination with the National ITS Architecture standards efforts, can make integration easier by allowing the implementation of different manufacturers' components and systems within a common communications infrastructure, as illustrated in Figure 2.6-4. More background on the NTCIP family of standards is provided in Appendix A.

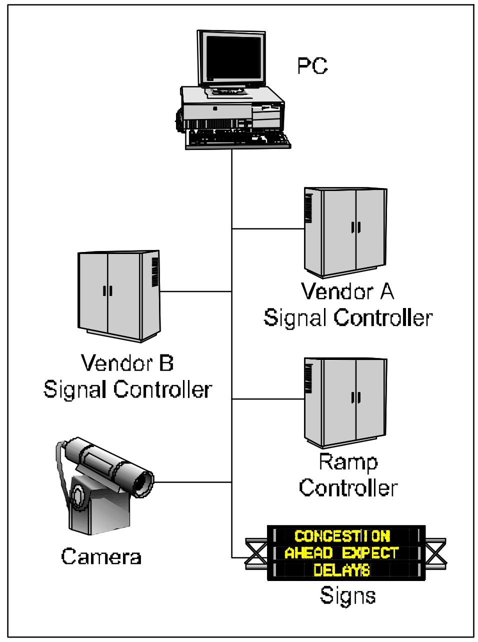


Figure 2.6-5. NTCIP Standard

Given the status of NTCIP development, the State has decided to investigate incorporating it in the specifications for new controllers for this project. A major benefit of NTCIP will be the ability it will provide to control traffic signal controllers, variable message signs, video surveillance cameras, and traffic sensors using the same communications channel.

2.6.1.4 Funding, Procurement, and Implementation

The final step of the project development process was the preparation of the system procurement documents. In preparing the PS&Es, the consultant recommended conducting a telecommunications analysis to quantify and characterize required information flows in the system, and evaluating different telecommunications options, including telecommunications service leasing possibilities.

Cost Analysis

During the MIS study, the *Cost Analysis* document provided sufficient information to produce a reasonable order-of-magnitude cost estimate for both capital and recurring costs. The public agencies used this estimate for budgeting purposes.

Cost Assumptions

- 54 points on freeway mainline will have loops deployed.
- 35 additional video cameras will be deployed.
- 4 VMS will be deployed.
- 8 interchanges will have ramp metering installed.
- Software is off-the-shelf.
- Communications are leased from a communications service provider.

To generate costs, one should list the equipment packages associated with each market package; then, using the Cost Analysis document worksheets, calculate order-of-magnitude costs. (All prices are in 1995 dollars. The costs shown in the tables below utilize the *high* unit price cost.) These costs are used strictly for up-front planning purposes.

Costs for the Freeway-Incident system scenario are summarized in Table 2.6-1. Tables 2.6-2 through Table 2.6-5 show how each market package cost was calculated and built up from individual equipment package cost. Cost information is separated into initial capital investment required and recurring operations and maintenance costs. More detailed cost estimates will be prepared at each of the program stages using actual vendor prices.

Table 2.6-1. Cost for Freeway and Incident Management System Upgrade Scenario

Freeway-Incident Scenario		
Initial Capital Investment (By Market Package)	Equipment Package Roll-Up	Cost
Freeway Control	TMC Freeway Control (Table 2.6-2)	$ 251,000
Freeway Control	Traffic Maintenance (Table 2.6-2)	$ 35,000
Freeway Control	Roadway Freeway Control (Table 2.6-2)	$ 400,000
Freeway Control	TMC Incident Detection (Table 2.6-2)	$ 328,000
Freeway Control	Roadway Incident Detection (Table 2.6-2)	$ 2,800,000
Network Surveillance	Collect Traffic Surveillance (Table 2.6-3)	$ 425,000
Network Surveillance	Roadway Basic Surveillance (Table 2.6-3)	$ 432,000
Traffic Information Dissemination	TMC Traffic Information Dissemination (Table 2.6-4)	$ 145,000
Traffic Information Dissemination	RW Traffic Information Dissemination (Table 2.6-4)	$1,000,000
Incident Management System	Emergency Response Management (Table 2.6-5)	$ 97,000
Incident Management System	TMC Incident Dispatch Coordination/Communication (Table 2.6-5)	$ 113,000
	Total Capital Investment	$6,026,000
Operations and Maintenance (By Market Package)	Equipment Package Roll-Up	Cost
Freeway Control	TMC Freeway Control (Table 2.6-2)	$ 258,000
Freeway Control	Traffic Maintenance (Table 2.6-2)	$ 50,000
Freeway Control	Roadway Freeway Control (Table2.6-2)	$ 2,000
Freeway Control	TMC Incident Detection (Table 2.6-2)	$ 716,000
Freeway Control	Roadway Incident Detection (Table 2.6-2)	$ 140,000
Network Surveillance	Collect Traffic Surveillance (Table 2.6-3)	$ 120,000
Network Surveillance	Roadway Basic Surveillance (Table 2.6-3)	$ 43,000
Traffic Information Dissemination	TMC Traffic Information Dissemination (Table 2.6-4)	$ 110,000
Traffic Information Dissemination	RW Traffic Information Dissemination (Table 2.6-4)	$1,000,000
Incident Management System	Emergency Response Management (Table 2.6-5)	$ 5,000
Incident Management System	TMC Incident Dispatch Coordination/Communication (Table 2.6-5)	$ 113,000
	Total Operations and Maintenance Cost / Year	$2,557,000

Table 2.6-2. Cost for Freeway Control Market Package

Freeway Control Market Package (8 Ramps)		
Initial Capital Investment	**Roadway Freeway Control Equipment Package**	**Cost**
	- 8 Ramp Meters (8 @ 50,000).	$ 400,000
	Sub Total	**$ 400,000**
Operations and Maintenance	**Roadway Freeway Control Equipment Package**	**Cost**
	- Ramp Meter Maintenance @ 5% Capital Cost	$ 2,000
	Sub Total	**$ 2,000**
Initial Capital Investment	**TMC Freeway Control Equipment Package**	**Cost**
	- Software and Integration and 1 year maintenance.	$ 220,000
	- Hardware (3 Workstations)	$ 30,000
	- TMC to Roadside Communications - DS 1	$ 1,000
	Sub Total	**$ 251,000**
Operations and Maintenance	**TMC Freeway Control Equipment Package**	**Cost**
	- TMC to Roadside Communication - DS 1	$ 8,000
	- Operators (2 @ 50% time)	$ 100,000
	- Maintenance Technicians (2 @ 75,000)	$ 150,000
	Sub Total	**$ 258,000**
Initial Capital Investment	**Traffic Maintenance Equipment Price**	**Cost**
	- Software and Database Add-on	$ 35,000
	Sub Total	**$ 35,000**
Operations and Maintenance	**Traffic Maintenance Equipment Package**	**Cost**
	- Transportation Engineer (1 @ 50% time)	$ 50,000
	Sub Total	**$ 50,000**
Initial Capital Investment	**Roadway Incident Detection Equipment Package**	**Cost**
	- Adv. CCTV w/ Detection Algorithm (35 @ 40,000)	$ 1,400,000
	- Towers (35 @ 40,000)	$ 1,400,000
	Sub Total	**$ 2,800,000**
Operations and Maintenance	**Roadway Incident Detection Equipment Pkg.**	**Cost**
	- CCTV Maintenance @ 10% capital cost	$ 140,000
	Sub Total	**$ 140,000**
Initial Capital Investment	**TMC Incident Detection Equipment Package**	**Cost**
	- Hardware (4 servers)	$ 50,000
	- Hardware (5 workstations)	$ 30,000
	- Software	$ 100,000
	- Integration	$ 100,000
	- Laser Printer (2)	$ 3,000
	- 19" Video Monitors (5)	$ 15,000
	- Video Wall	$ 30,000
	Sub Total	**$ 328,000**
Operations and Maintenance	**TMC Incident Detection Equipment Package**	**Cost**
	- Operators -4 Analysts @ 100,000, 1 Mgr @ 150,000	$ 550,000
	- Equipment O&M @ 5% Capital Cost	$ 16,000
	- Maintenance Technicians (2 @ 75,000)	$ 150,000
	Sub Total	**$ 716,000**

Table 2.6-3. Cost for Network Surveillance Market Package

Network Surveillance Market Package (35 Cameras, 54 Loops)			
Capital Investment	**Collect Traffic Surveillance Equipment Package**		**Cost**
	- Processor and Software	$	165,000
	- Integration	$	250,000
	- TMC to Roadside Communications - DS 3	$	5,000
	- Roadside to TMC Communication - DS 3	$	5,000
	Sub Total	**$**	**425,000**
Operations and Maintenance	**Collect Traffic Surveillance Equipment Package**		**Cost**
	- TMC to Roadside Communication - DS 3	$	50,000
	- Roadside to TMC Communication - DS 3	$	50,000
	- Maintenance for & Software @ 5% Capital Cost	$	20,000
	Sub Total	**$**	**120,000**
Capital Investment	**Roadway Basic Surveillance Equipment Package**		**Cost**
	- 54 Loops @ $8,000	$	432,000
	- 35 Video Cameras -under RW Incident.Detection Detection)	$	
	- 35 Camera Poles -under RW Incident. Detection	$	
	Sub Total	**$**	**432,000**
Operations and Maintenance	**Roadway Basic Surveillance Equipment Package**		**Cost**
	- Loop Maintenance @ 10% Capital Cost	$	43,000
	- Camera Equipment Maintenance @ 2% Capital Cost	$	
	Sub Total	**$**	**43,000**

Table 2.6-4. Cost for Traffic Information Dissemination Market Package

Traffic Information Dissemination Market Package (4VMS)			
Capital Investment	**TMC Traffic Information Dissemination Equipment Package**		**Cost**
	- Hardware (1 Workstation)	$	10,000
	- Software	$	24,000
	- Integration	$	110,000
	- Roadside to TMC Communication - DS 0	$	1,000
	Sub Total	**$**	**145,000**
Operations and Maintenance	**TMC Traffic Information Dissemination Equipment Package**		**Cost**
	- 1 Operator @ $100,000	$	100,000
	- Maintenance @ 5% Capital Cost	$	7,000

	- Roadside to TMC Communication - DS 3	$ 3,000
	Sub Total	**$ 110,000**
Capital Investment	**Roadway Traffic Information Equipment Package**	**Cost**
	- 4 Variable Message Signs @ $100,00	$ 400,000
	- 4 VMS Support Structures @ $150,000	$ 600,000
	Sub Total	**$ 1,000,000**
Operations and Maintenance	**Roadway Traffic Information Equipment Package**	**Cost**
	- Maintenance @ 5% Capital Cost	$ 50,000
	Sub Total	**$ 50,000**

Table 2.6-5. Cost for Incident Management System Market Package

Incident Management System Market Package (10VMS)		
Capital Investment	**TMC Incident Dispatch Coord/Comm Eq. Pkg. Equipment Package**	**Cost**
	- Hardware (1 Workstation)	$ 3,000
	- Software	$ 15,000
	- Integration	$ 180,000
	- TMC to EM Communication - DS 0	$ 1,000
	Sub Total	**$ 199,000**
Operations and Maintenance	**TMC Incident Dispatch Coord/Comm Eq. Pkg.**	**Cost**
	- Incident Management Coordinator @ $100,000	$ 100,000
	- Maintenance @ 5 Capital Cost	$ 10,000
	- Roadside to TMC Communication - DS 3	$ 3,000
	Sub Total	**$ 113,000**
Capital Investment	**Emergency Response Mgmt. Eq. Pkg.**	**Cost**
	- Communication to/from TMC	$ 1,000
	- Emergency Response Plan Database	$ 25,000
	- I/F with Vehicles and Other Agencies	$ 1,000
	- Vehicle Tracking Software	$ 40,000
	- Real Time Traffic Coordination	$ 10,000
	- Workstations	$ 20,000
	Sub Total	**$ 97,000**
Operations and Maintenance	**Emergency Response Mgmt. Eq. Pkg.**	**Cost**
	- Maintenance @ 5% Capital Cost	$ 5,000
	Sub Total	**$ 5,000**

2.6.2 Freeway-Arterial Coordination (Using User Service Requirements)

In this scenario, the State and City traffic management agencies agreed to work together to better manage traffic congestion situations. *This scenario illustrates the use of user service requirements as an approach for guiding the development of functional requirements for a system.*

Background

A major challenge to managers of traffic signal control systems is the coordination of traffic control strategies across transportation facilities operated by different agencies. Coordination between different transportation facilities includes freeway and surface street coordination, coordination of surface street networks in adjacent jurisdictions, and coordination of surface streets and bridges and tunnels. When traffic flow in one portion of the transportation network breaks down, delays and congestion can spill over into other transportation facilities. By coordinating information and control strategies, traveler safety and travel times can be improved while reducing delays and traffic congestion by balancing the traffic loads between resources.

Freeway-Arterial coordination is effective when the demand in one transportation facility that is approaching capacity can be balanced with excess capacity available in an adjacent transportation facility. Managing and balancing the traffic demand in both networks can minimize delays and congestion in both networks. One issue related to freeway-arterial coordination is that of non-recurring delays and traffic on the mainline freeway. Vehicles on the freeway will tend to divert onto alternate routes to reach their destination when congestion occurs on the mainline. These routes may include parallel service roads and arterials in the vicinity of the freeway. This situation generally results in increased traffic demand on service roads and arterials, possibly increasing beyond the capacity of the existing roadway and the signal timing patterns, resulting in significant traffic congestion on the surface streets. The surface street managers, unaware of the delays on the freeways, cannot adjust the signal timing patterns in time to handle the increased volumes, and the resulting traffic congestion cannot be prevented from spreading to other roadways within their jurisdiction.

Another problem which occurs is the ramp metering rate at a freeway entrance may not be able to accommodate the traffic demand at the on-ramp, resulting in the queue on the ramp spilling back onto the surface street network. The spill-back may cause a breakdown of the traffic flow on the service road or of the signalized intersections upstream from the ramp entrance. With the latter situation, vehicles are unable to enter the on-ramp because of the upstream queue. They might block the intersection or create further spill-back on all the approaches to the signalized intersection, resulting in further congestion and delays.

This Scenario

In this scenario, the City traffic engineering agency responsible for traffic management on the parallel arterials met with the State DOT to discuss how they can better respond to incident-related increased demand situations. The City operates a Traffic Management Center containing a centralized computerized traffic signal control system. Timing plans are implemented on a time-of-day, day-of-week basis. Currently, the City’s traffic signal control system operates independently of the State’s Freeway Management System, i.e., it is wholly self-contained and does not communicate with any other agency transportation management system.

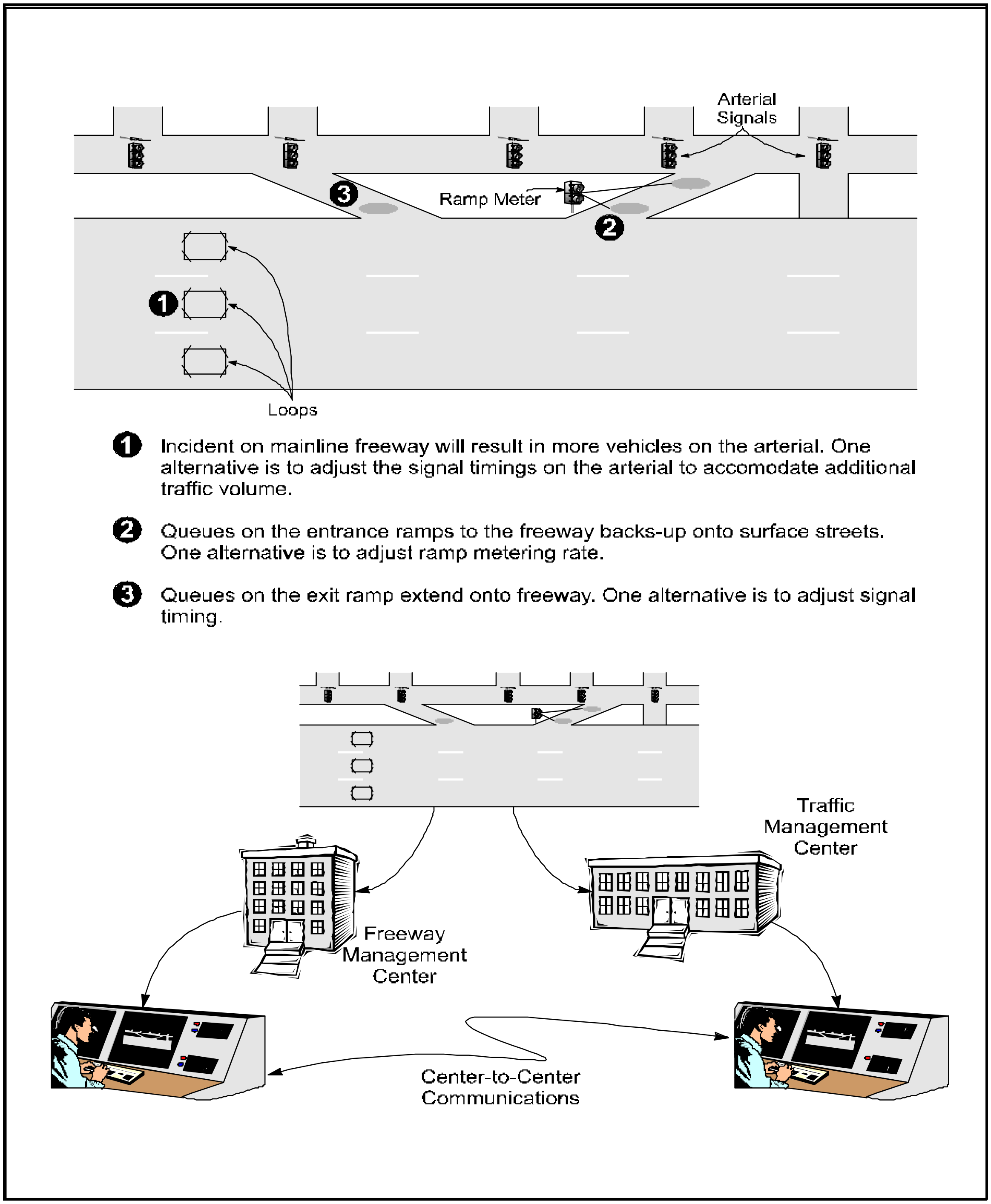
The State DOT and City traffic engineering agency agreed in principle to improve communications to better manage traffic during major incident situations. A task force was appointed to investigate the situation and report back to decision-makers in both agencies. The Freeway-Arterial scenario is illustrated in Figure 2.6-6.

2.6.2.1 Identification of Problems and Needs

The first job of the joint task force was to identify and refine all of the relevant transportation needs, objectives or problems.

Existing System

The State DOT operates a freeway management system which includes ramp meters at the freeway entrances and detectors on the mainline. The traffic signals at the



freeway exit ramps are also operated

Figure 2.6-6 Freeway-Arterial Coordination Scenario

by the State. The State's freeway management system and the State's traffic signal control system do not currently communicate with each other. Additionally, the City traffic engineering agency operates the traffic signals along an arterial that runs parallel to the freeway. The City traffic signal system and the State's freeway management systems do not currently communicate with each other.

Objectives

The State and City agencies agreed to upgrade their systems to cooperate on handling of incident traffic management. The task force identified the following needs:

- The City must know as soon as possible when a freeway incident has occurred that has the potential to cause major traffic diversions from the freeway to parallel arterials.
- The City must develop incident response signal timing plans that will accommodate larger through traffic volumes on the arterial. The timing at traffic signals downstream of freeway ramp exits will be especially critical.
- Drivers need to be informed in advance of freeway entrance ramps when a major incident exists on a nearby downstream freeway link so they may select alternative routes.
- Information on current arterial conditions needs to be disseminated to the public to avoid inadvertently causing an even worse problem as a result of too much diversion to arterials.
- If sufficient capacity exists in the arterial system, traffic can be diverted from the freeway to the arterial system to improve overall traffic flow through the corridor.
- The ramp metering rate can be adjusted to allow increased flow of vehicles onto the freeway system (assuming there is sufficient available capacity), thus reducing congestion on the arterial system. The signal timing of the traffic signal downstream of the exit ramp and the arterial signals further downstream can be adjusted to increase the flow of vehicles onto the arterial system, thus reducing queues at the freeway exit ramp.

In addition, the State and City agencies have been approached by an Information Service Provider (ISP) who would like to disseminate real-time traffic information for the region to travelers, via local radio and television broadcasters.

2.6.2.2 Identification of Solutions

Freeway-Arterial coordination is successful when the respective facility managers are aware of traffic conditions on each other's portion of the transportation network, and they coordinate a timely response according to those conditions. Coordination between the two networks will involve using the field devices (VMS, ramp meters, signal controllers, CCTV, etc.) on their respective systems to implement cooperative responses.

One alternative to integrating the freeway management system and the arterial traffic signal control system is to develop new software on both systems which would handle communications and requests for signal timing or ramp meter adjustment. A second alternative is to introduce an ancillary system which would manage communications between the State's freeway management system and the City's traffic signal control system. A third alternative is to consider placing the traffic signals at the freeway entrance and exit ramps, currently under control of the State, under the jurisdiction of the City, which would enable the City to coordinate their operations. The third alternative also requires that the City have access to the operational status of the freeway system.

The task force also agreed to investigate the **Traffic Control**, **Incident Management**, and **En-Route Driver Information** user services to determine if their underlying requirements and physical and logical architecture definition could be used to support the planning and design of the project.

Other Considerations

The task force also identified several capabilities that might be included in the solution.

- Inclusion of the arterial operations center as a node on a wide area network that will allow freeway incident alarm messages to be received at the arterial operations center, and allow the arterial operators to communicate with traveler information service providers

- Dial-in capability that will allow arterial signal system operators to monitor the freeway status map and selected freeway video surveillance cameras on monitors

- Development of arterial incident response timing plans that incorporate gating (storing traffic upstream of congested locations) and reverse progression (to clear queues and help prevent intersection blockage) strategies

- Installation of variable message signs on key arterials in advance of freeway entrance ramps

- Installation of video cameras at critical locations along arterials

- Agreement on information that will be exchanged (queue lengths, travel speeds, estimated duration of delay, ramp metering rate, signal timing pattern in effect, signal splits, etc.), and how information will be exchanged (communications media, protocol, data format, etc.)

- Development of operating agreements detailing responsibilities during incident situations. This includes agreement on common control strategies for handling delays and problems as they occur, agreement in advance on what thresholds will trigger certain control strategies to be placed into effect, and agreement that control strategies should be employed judiciously such that they provide an overall benefit to the transportation network. For example, freeway managers should not encourage motorists to use the service roads or arterials if excess capacity is not available on the surface street network. Conversely, the ramp metering rate for the on-ramp should not be increased if it is determined that the impact on the mainline freeway will have a significant adverse effect.

The State and City have agreed to investigate the use of ITS standards for communications. The City has also agreed to allow the State to collect regional traffic data and provide it to an ISP in the future—this deployment will be used as a model for the rest of the State.

2.6.2.3 Planning and Design

At this point, the State DOT, acting on behalf of the State and City, procured the services of a consultant to plan, design and implement the solutions identified above. The State and City agencies asked the consultant to use the selection and tailoring of user service requirements a way to guide the development of functional requirements for the project. The Travel and Transportation Management user services that apply to this scenario are Traffic Control, Incident Management, and En-Route Driver Information. A Functional Description document was prepared, along with an Operations Plan detailing the operating agreements referred to above.

User Service Requirements Illustration

User services are defined in the National ITS Architecture Traceability document. As an example, a list of requirements from Appendix A of the Traceability document that defines the "Traffic Control" user service in detail is provided below with the specific requirements selected to be applied in this design shown as bolded. Similar tables were produced for the other two user services that were investigated. Appendix B of the Traceability document was then used to select the process specifications (P-specs) that correspond to the selected user service requirements. These were used in the preparation of the Functional Description document, along with many additional locally derived requirements and operational concepts forwarded from the task force.

The physical data flows needed to implement the necessary portions of the Traffic Control user service were selected from Appendix A of the Physical Architecture document and were incorporated into the procurement specification by the consultant. Examples of user services and dataflows are provided below.

TRAFFIC CONTROL (EXCERPT)

Traffic Control provides the capability to efficiently manage the movement of traffic on streets and highways. Four functions are provided which are **(1) Traffic Flow Optimization**, (2) Traffic Surveillance, **(3) Control Function**, and **(4) Provide Information**. This will also include control of network signal systems with eventual integration of freeway control.

1.6.1 Traffic Control shall include a Flow Optimize function to provide the capability to optimize traffic flow.

1.6.1.1 The Flow Optimize function shall employ control strategies that seek to maximize traffic-movement efficiency.

1.6.1.1.1 Traffic-movement control shall manage movement of traffic on streets.

1.6.1.1.2 Traffic-movement control shall manage movement of traffic on highways.

1.6.1.1.3 Traffic-movement control shall include the goal of minimizing delay times.

1.6.1.1.4 Traffic-movement control shall include the goal of minimizing energy use.

1.6.1.1.5 Traffic-movement control shall include the goal of minimizing air quality impacts due to traffic.

……..

1.6.1.3 Flow optimize shall be implemented in a manner that seeks to optimize traffic movement over a large geographic area.

1.6.1.4 Flow optimize shall include a Control function that is responsive to both the current demand as well as the expected demand.

1.6.1.5 Flow Optimize shall provide the capability to predict travel patterns.

1.6.1.6 The Control Function shall include the use of data acquired from traffic surveillance as feedback to the control strategies.

1.6.1.7 Implementation of the Control Function shall include strategies that account for at least: Human factors and Driver/traveler behavior and expectancies.

1.6.2 Traffic Control shall include a Traffic Surveillance function.

………

1.6.3.1 The Device Control Function shall include a "real-time" traffic-adaptive control capability.

1.6.3.2 The real-time traffic-adaptive control portion of the Control Function shall be an area wide control to include several jurisdictions.

1.6.3.2.1 The area wide control shall be implemented in an integrated and consistent manner that avoids the issuance of conflicting controls.

1.6.3.2.2 The area wide control shall be implemented in a manner that permits the following types of vehicles to have preference over other vehicles being controlled; Transit, HOV, Emergency Medical Service Vehicles.

……….

1.6.3.3.1 Device Control shall include the capability to control traffic signalization, including rapid modification of signalization parameters to respond to traffic requirements.

1.6.3.3.2 Device Control shall include the capability to control dynamically traffic signing.

1.6.3.3.3 Device Control shall include the capability to control freeway ramp metering.

1.6.3.3.4 Device Control shall include the capability to exercise dynamic control over the infrastructure (such as reversible-lanes, turning restrictions, etc.).

……….

1.6.4 The Control Function shall provide traffic control information to other elements of the ITS, including but not limited to: Independent Service Provider, In-vehicle navigation, Trip planning, En-Route Driver Information, Routing systems, and Fleet management systems.

Physical Data Flows Required Selected from Appendix A of Physical Architecture.

(Example)

Traffic Management to Information Service Provider: traffic information messages

Traffic Management to Other Traffic Management Center: Traffic Management Center coordination messages

Traffic Management to Roadway Subsystem: signage data messages

Traffic Management to Traffic Operations Personnel: traffic operations data messages

Traffic Operations Personnel to Traffic Management: traffic control commands messages

Applicable Standards - NTCIP Class E

The NTCIP Class E Profile—Center-to-Center "E"xchange—is intended for data exchange between transportation management centers. The Class E profile will be compatible with Internet community standards and is designed for high-speed communications. The NTCIP Class E Profile addresses the need for a protocol that satisfies the communication requirements between transportation management centers, and includes information service providers. The primary feature of this profile is the reliable transfer of data and support for routing between network nodes in a secure environment. The Class E Profile can also be used for the reliable exchange of data between field devices and controllers that are on public data networks. (See Standard Requirements Package 6: Traffic Management Subsystem to Other Centers.)

2.6.2.4 Funding, Procurement and Implemenation

In consultation with the task force, the consultant then completed preparation of the design Plans, Specifications, and Cost Estimates (PS&Es). The State and County have decided to implement a regional traffic control concept and will use the NTCIP Class E as a standard for communicating information between systems. The State will fund the development and installation of a Regional Traffic Control subsystem to act as a gateway between the Freeway Management System, the Arterial Traffic signal control Systems, and the ISP. The County and State will upgrade their computer systems to be compatible with the NTCIP Class E Profile. In addition, the Regional Traffic Control subsystem will integrate communications and control between the State's freeway intersection control elements. Figure 2.6-7 depicts the integration of the two systems which will enable the solutions identified by the task force.

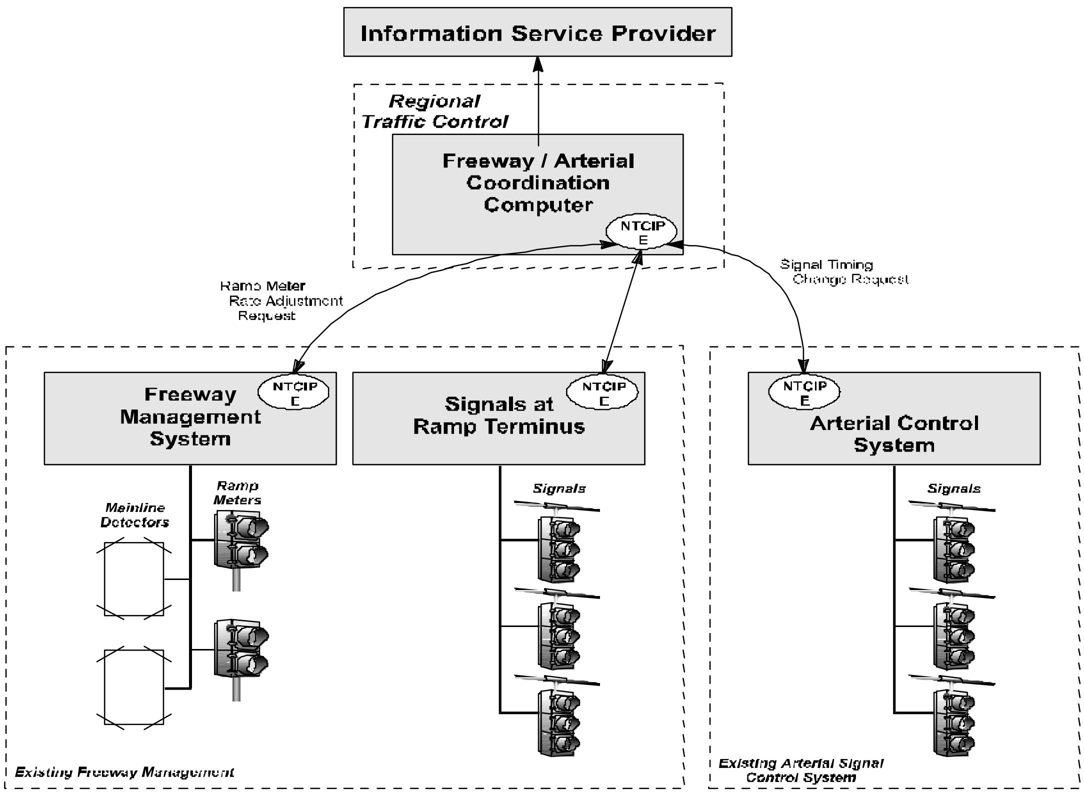


Figure 2.6-7. Freeway-Arterial Coordination

2.7 Summary

This section presented the key concepts of the National ITS Architecture and discussed in some detail how it can be applied to freeway management or incident management project development activities. A pair of freeway and incident management project application scenarios were presented which used realistic examples to illustrate these methods.

Some of the key themes of this section include:

- The key concepts and elements of the National ITS Architecture as presented in Sections 2.4.1– 2.4.5 are interrelated and traceable in a variety of ways.
- The National ITS Architecture tools are intended to augment and support existing ITS project development processes, and should be applied with engineering judgment in that context.
- There are many ways to apply the National ITS Architecture to the project development process.
- The National ITS Architecture tools are most applicable in the early stages of project development.
- The National ITS Architecture can be used to provide project developers with additional options to consider for information exchanges and functionality that may not have initially been conceived at the outset of the project.
- Using the National ITS Architecture should not be viewed as an all-or-nothing requirement; rather, the material can be used as is, tailored, dropped, or added to as appropriate for the situation.
- The National ITS Architecture is available in several formats, including paper documents, Microsoft Access™ relational databases, and a linked HTML model, which provides access through a linked model.
- Several entry points or methods are also available which make accessing the applicable information more convenient.

A summary of how the National ITS Architecture can be used to support project development activities and the most relevant resource material is provided below:

Identification of Needs or Problems (Section 2.5.1)

- The National ITS Architecture can assist agencies in identifying ITS goals and objectives that are specific to their needs.
- The Vision Statement can also serve to foster general ideas about the types of local needs and problem that ITS can be used to address.

Useful National ITS Architecture Documents: Mission Definition, Vision Statement

Identification of Solutions (Section 2.5.2)

- T Agencies can use two major approaches for identifying possible solutions that are supported by the National ITS Architecture.
  - , User Services
  - , Market Packages
- T Evaluation and Implementation Strategy documents have supporting information that can be referenced.

Useful National ITS Architecture Documents: Traceability Matrix, Implementation Strategy, Performance and Benefits Study

Planning and Design of the Solution (Section 2.5.3)

- T The National ITS Architecture can be used as an input to defining project or system functional requirements. Potential approaches include:
  - Ë *User service requirements* - The user service requirements associated with the proposed solution can be evaluated for their applicability to the project.
  - Ë *Market packages* - The high-level architecture defined using the market packages can be further refined by examining the logical architecture elements that support these subsystems and architecture flows.
  - Ë *Physical Architecture Subsystems* - Agencies can determine the relevant subsystems associated with a given project and use this as an entry point to accessing the underlying architecture definition.
- T The physical architecture can be used to support the definition of the information exchange requirements for a given project.
- T The Standards Requirements document contains detailed information on the requirements for 12 high-priority standards packages, which can be helpful towards the identification of standards for a given project.

Useful National ITS Architecture Documents: Logical Architecture, Physical Architecture, Traceability, Theory of Operations, Communications Document, Standards Requirements Document

Funding, Procurement, and Implementation (Section 2.5.4)

- T The Cost Analysis can be used to help estimate planning-level costs for the project. These costs should be applied cautiously and should not be used as a recipe for determining the actual costs of ITS deployments.
- T The evaluation documents and the Implementation Strategy can also be used as a general resource during this final phase of project development.

Useful National ITS Architecture Documents: Physical Architecture, Implementation Strategy, Cost Analysis

3. Regional ITS Planning

Just as individual highways fit into a larger regional transportation system, freeway and incident management systems should fit into a larger regional transportation management context. Because the sharing of information between agencies and the coordination of operations are central characteristics of ITS, a regional approach is particularly desirable. Regional ITS planning activities and investment decisions should be carried out within the framework of the overall transportation planning process and need to be viewed in that context.

Why is regional ITS planning a good idea[1]?

Ë It provides a mechanism for bringing stakeholders together to address transportation operations and management issues of mutual concern.

Ë It promotes greater consideration of systems management and operations as part of a region's overall approach to meeting transportation needs.

Ë It facilitates decisions on which ITS services and strategies apply to local needs and transportation problems.

Ë It allows agencies to coordinate efforts such that future projects will be compatible, resulting in cost savings and easier integration of systems over time.

Ë It facilitates reaching agreements between agencies on future operational strategies and information exchanges to be pursued.

Ë It fosters consideration of and attention to detail which is required to ensure coordinated and cost-effective operation of ITS.

Ë It provides an opportunity to coordinate long term implementation of ITS and establish general deployment strategies and priorities.

The National ITS Architecture provides an excellent departure point for those engaged in a regional ITS planning process. The results of this process will set forth how individual transportation management systems operated by different agencies in different jurisdictions should work together to provide better transportation management and information services to the traveling public. These activities provide a framework for thinking about the needed relationships among institutions, as well as technical issues such as the information needs of each transportation

[1] **Adapted from "Integrating Intelligent Transportation Systems within the Planning Process: An Interim Handbook", TransCore, August 1997, pages 2-8 and 5-2.**

operating agency, the sources of that information, and how that information can best be exchanged between the different agencies.

The processes discussed below provide a way of approaching regional ITS planning in a systematic way, using material from the National ITS Architecture as a guide and departure point. Use of these or similar processes in regional ITS planning, and following the processes discussed in Chapter 2 to develop individual projects, allows for sensible evolution of an improved regional transportation management system that will accommodate emerging national standards and best practices.

Ideally, the planning activities discussed in this section would be carried out prior to the implementation of individual projects as discussed in Section 2. Projects that are developed after regional ITS planning decisions have been made can be designed to implement a portion of the overall ITS strategy and can make use of the information exchanges already decided upon. However, regional ITS planning activities do not always occur prior to the implementation of specific projects. Projects that are implemented without the guidance of regional ITS planning can still make use of the National ITS Architecture as described in Section 2.

This section is not intended to cover all aspects of the transportation planning process and the activities and products which comprise it. For further information on how ITS should be included within the planning process, refer to the Interim Handbook on Integrating Intelligent Transportation Systems within the Planning Process (TransCore, August 1997).

Regional ITS planning can be done using a two-phase approach: 1) concept planning, and 2) implementation planning. The material that follows discusses the activities that are involved in each of these steps and points out where National ITS Architecture material can be helpful. For completeness, short sections are then provided for project deployment and evaluation, which are necessary to implement and monitor the effectiveness of the initiatives decided upon in the planning process.

3.1 Concept Planning

Concept planning addresses the questions of what transportation management systems and improvements are needed in the region, and how individual systems can be integrated so that individual agencies can do a better job of providing services to the public. Concept planning supports the development of a consensus for a regional transportation management strategy. A useful analogy is to think of it as a strategic plan. Strategic plan development is typically a participative process that results in a vision and strategy for the future for an organization. Similarly, regional ITS concept planning should result in a vision and strategy that reflects the needs of the various stakeholders in a region, and builds upon systems and relationships already in place.

Concept planning should consider the problems as well as the existing transportation goals and objectives of a region as determined through the transportation planning process, and use these as a basis to compile a set of relevant ITS or transportation management goals, objectives, and solutions. It may be advisable to revisit some of the assumptions in the existing plan, however, to see whether new players can be identified who have a stake in ITS, and to broaden the definition of transportation needs to account for the expanded capabilities of ITS. This periodic review and revision fits with the overall regional transportation planning process.

Typical steps involved in concept planning include:

- Stakeholder identification
- Identification of existing ITS or transportation management functions
- Identification of regional needs
- Identification of needed ITS or transportation management functions and improvements

Products of concept planning may include:

- A mission statement
- A vision statement
- Needed transportation management functions and improvements
- Assessment measures
- A strawman regional architecture

3.1.1 Stakeholder Identification

The list of stakeholders will naturally include all of the traditional transportation management agencies in a region, including the state highway or transportation department, county and city operating agencies, and public transportation agencies. The Metropolitan Planning Organization (MPO) is clearly also an important stakeholder. Effective transportation management planning also includes consideration of the views of other agencies, such as emergency service providers (ambulance, fire, police) and private traveler information service providers.

Concept planning provides stakeholders with a process for identifying transportation problems as well as potential ITS or transportation management solutions to the problems. Identifying what is needed before determining how to do it is an important aspect of both planning and systems engineering. Looking at needs from the perspectives of different stakeholders is necessary to ensure that the total requirements of a regional transportation management system are considered as the system concept emerges and projects are planned and implemented.

3.1.2 Identification of Existing ITS or Transportation Management Functions

This is a comprehensive inventory of existing and planned projects/systems in a region. Information sharing or integration with other systems, whether existing or planned, should be identified. Existing systems may be characterized by:

- Ë The services provided
- Ë The stakeholders involved and their responsibilities
- Ë The technologies in place
- Ë The control and communications structure within the system.
- Ë The opportunity to include infrastructure into planned traditional transportation improvement projects (e.g., incorporating conduit into roadway re-construction jobs)
- Ë Information flows, including both information sources and recipients
- Ë Operating characteristics and responsibilities

3.1.3 Identification of Regional Needs

Regional transportation problems and needs that can potentially be addressed through ITS or transportation management solutions should be identified in the form of concise statements, such as reduce accidents at freeway ramp entrances, or improve detection of ice on bridges. These needs should be developed in the context of the needs, goals, and objectives already developed as part of the region's transportation planning process, because these have already been agreed on by the region's transportation stakeholders.

Specific objectives and measures of effectiveness (MOEs) can also be identified at this stage for use in future performance assessment. MOEs may be either qualitative or quantitative. Each objective identified through the concept planning process should have at least one MOE associated with it. The relative weights to be put on the MOEs by the various stakeholders may be quite different. The explicit assessment of these weights can form the basis for consensus building among the stakeholders to develop common goals and cooperative programs.

3.1.4 Identification of Needed ITS Functions and Improvements

Once needs have been determined, solutions can be identified. These solutions, or services, should be detailed enough to be useful in defining projects, identifying their interdependencies, and in guiding regional ITS architecture development. To facilitate the latter, the information sharing possibilities associated with each service should be identified. As defined in Section 2.5, ITS user services and market packages are useful categorizations that help identify transportation management solutions.

3.1.5 Concept Planning Products

As a method for documenting the outcome of the various steps discussed above, possible products from a concept planning effort include: a mission statement, vision statement, a regional ITS improvement plan, and a strawman architecture. As steps in regional ITS planning, these products begin to document the big picture of the future to guide future ITS project plans and implementations.

A *mission statement* is a concise, unambiguous statement of the primary goal or goals of the regional system. It should be brief, only a few paragraphs in length.

Useful National ITS Architecture Document: Mission Definition

A *vision statement* contains narrative text providing a non-technical description of the system concept from the viewpoint of various key user groups. It describes what the system will be like in the future, ranging anywhere from a 5- to 20-year period. It may highlight specific areas, such as information and communications; public transit; commercial vehicles; cooperation and coordination of systems; demand management; freeway management; incident management; and emergency services. A vision statement should use layman's language understandable to all stakeholders and may include magazine-style vignettes to convey descriptions of future scenarios for the general public.

Useful National ITS Architecture Document: Vision

A regional ITS improvement plan can be in the form of tables that depict the region's transportation management goals, objectives and assessment measures; existing ITS functions or services that address these goals and objectives; new services or improvements to be provided; and the information sharing characteristics of each.

Useful National ITS Architecture Documents: Mission Definition, Implementation Strategy, Traceability

A *strawman architecture* is a concept that helps to spur communication among those involved in the development of the regional transportation management system. It provides a starting point for discussions, development, and definition. This can take many forms, but typically represents an informal, immature view of the final implementation. It is based on experience and expertise gained from earlier system implementations, as well as current and future system requirements determined through the concept planning process.

A strawman architecture may illustrate:

- Transportation agencies and service providers involved with ITS deployment
- Applicable communications (center-to-center, center-to-roadside, center-to-vehicle, and vehicle-to-roadside) required to facilitate effective ITS
- Field ITS devices, both existing and planned

Figure 3.1-1 shows an example of a portion of a strawman regional architecture.

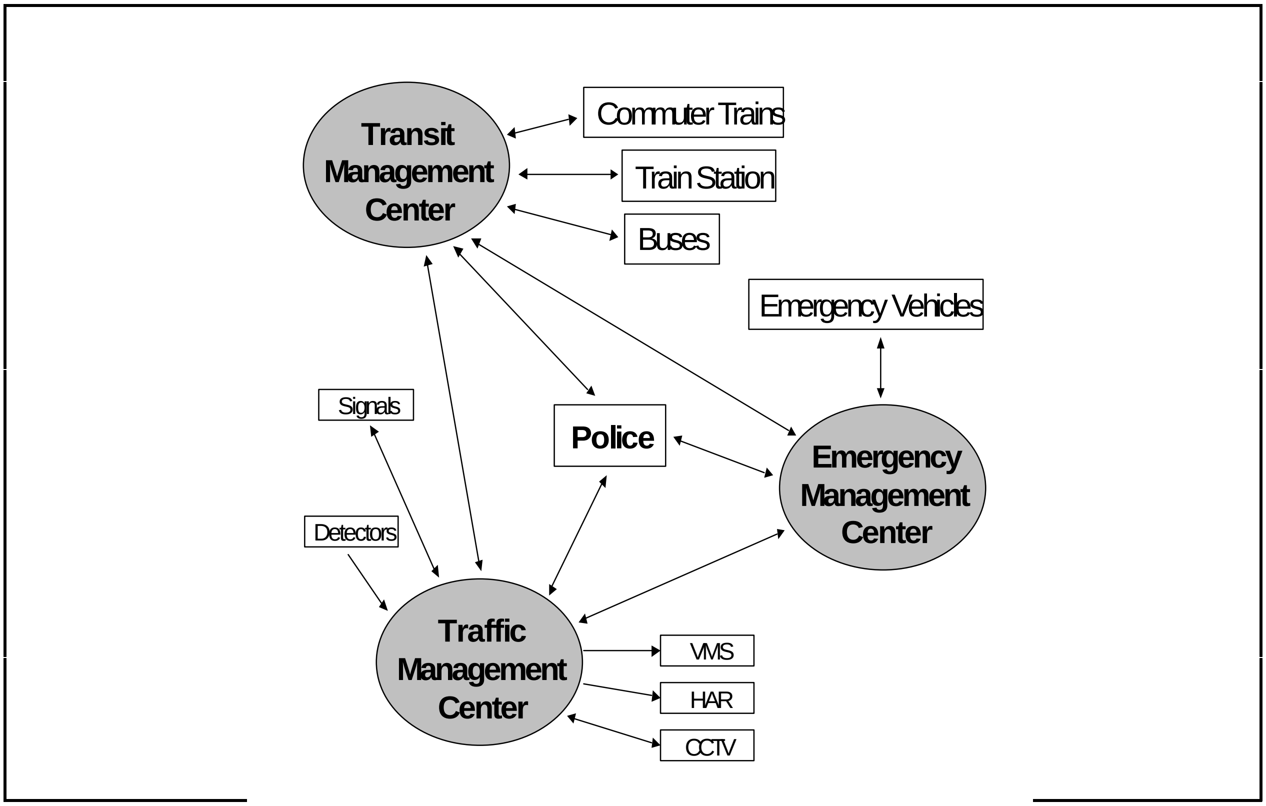


Figure 3.1-1. Example Strawman Regional Architecture

Useful National ITS Architecture Documents: Physical Architecture, Implementation Strategy

3.2 Implementation Planning

Implementation planning addresses the questions of how the stakeholder organizations in a region can organize to implement the results of the concept planning process. Just as strategic plans typically spawn an action plan, so should a regional ITS concept planning process lead to regional ITS implementation planning.

The steps involved in a typical implementation planning process may include:

- Stakeholder identification
- Development of a regional ITS architecture
- Identification of operational requirements
- Linking regional implementation plans with the region's transportation plan

- Time phasing of projects
- Developing regional technology agreements

The results of implementation planning will provide a roadmap for how to deploy an integrated, multi-modal transportation management system for a region. By identifying needed interfaces among systems in a region, agencies and service providers can incorporate them into their system requirements to accommodate integration with future ITS applications and systems. This prevents time-consuming and costly retrofits that might otherwise occur.

3.2.1 Stakeholder Identification

The development of an implementation plan should be supported by the same stakeholder organizations involved in concept planning. However, the representatives of these organizations that should participate in this stage will typically be individuals knowledgeable about the operations of the different transportation systems in the region. A structure that involves a steering committee, consisting of senior representatives from stakeholder organizations, and a technical committee, consisting of experienced operations personnel from these organizations, will serve the implementation planning process well.

Active participation during this stage is critical. Support will be needed for inclusion of ITS projects in the region's capital plan and, most importantly, to achieve buy-in to the operational concepts being formulated.

3.2.2 Development of a Regional Architecture

A regional architecture is a framework that provides a top-down approach for defining a regional transportation management system. A regional architecture will foster a logical and organized approach to regional ITS implementation and operation.

Regional ITS architecture development should build from the results of concept planning. The architecture should meld existing systems and services with new systems, services and improvements identified during concept planning. The regional architecture should:

- Identify the different transportation management systems in a region and how they will interact
- Allow multiple agencies, service providers, and users to communicate
- Show the responsibilities of the different organizations and service providers involved in the system

- Identify communications and data flows among participants
- Support development of open systems (i.e., systems with interfaces that use standard or known communications protocols)
- Incorporate the use of existing or planned systems
- Enable synergy among the different systems
- Allow for accommodation of new technologies in the future
- Provide a framework for multiple design choices
- Minimize ambiguity of system design
- Provide structure for future planning and growth
- Facilitate future system compatibility and interoperability

The architecture should identify all important physical transportation subsystems (by stakeholder/ agency) and external system interfaces and should show information flows between them. A functional description of each of the subsystems should also be developed. The architecture representation(s) should reflect both the existing and the proposed future ITS situation.

Using the logical and physical architecture concepts discussed in Section 2 and in the National ITS Architecture documents will assist agencies in the process of developing a regional architecture. Figure 3.2-1 shows how the physical architecture diagram from the National ITS Architecture can be used as the starting point for a depiction of a regional physical architecture.

The process of implementation planning will require that more detail on the interface requirements for each of the participating agencies be specified. Figure 3.2-2 shows an example of how the overall interface requirements vary among the four traffic management systems in a hypothetical region called Anytown. The architecture flows that are allocated are associated with the Network Surveillance, Regional Traffic Control, and Traffic Information Dissemination Market Packages. As can be seen, no two agencies have precisely the same set of allocated architecture flow requirements since each agency has individual needs and resources for ITS applications. Developing this level of detail will enable each participating agency to view how they fit into the overall transportation management picture in the region.

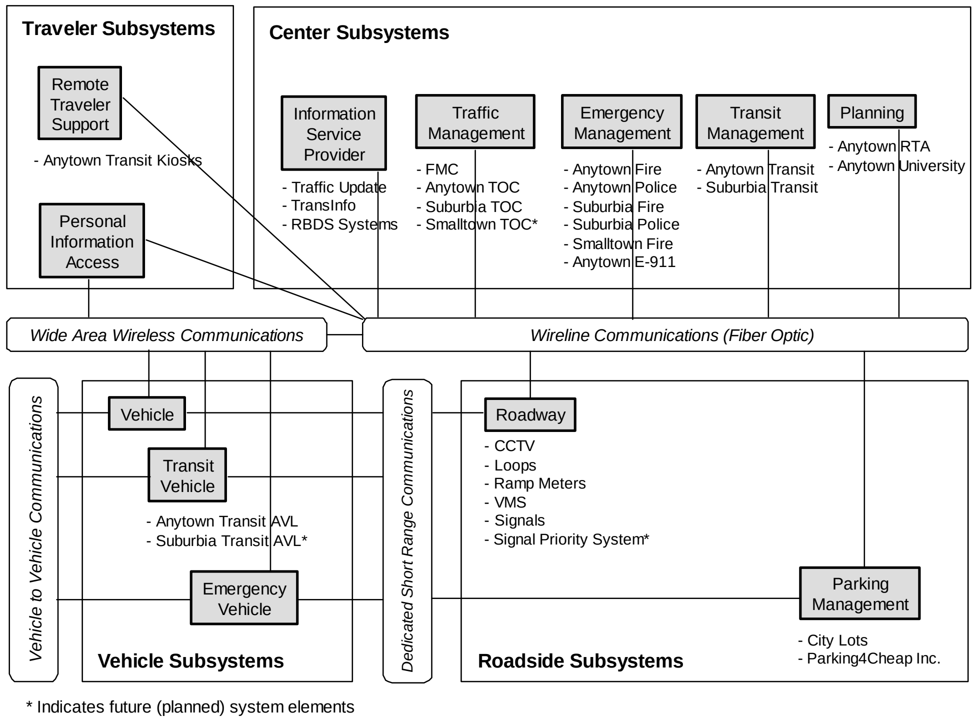


Figure 3.2-1. Example Regional Physical Architecture

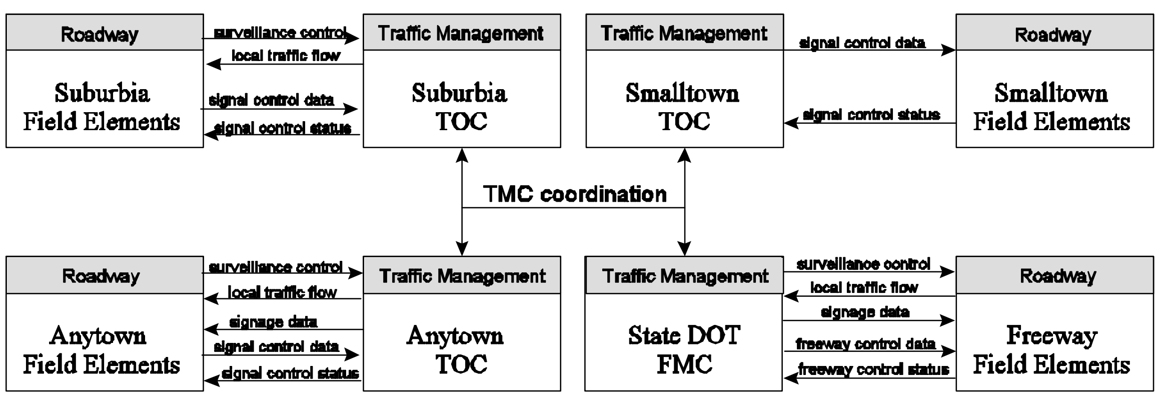


Figure 3.2-2. Regional Traffic Control Architecture Flows Applied in the Anytown Region

There are several ways to define the regional architecture at the appropriate level of detail by using the National ITS Architecture information as a starting point. One potential method is illustrated below:

Using the National ITS Architecture to Guide Regional Architecture Development

1. Determine the general subsystems from the National ITS Architecture which roughly correspond to regional stakeholders or service providers and populate with actual agency names. More than one agency may be identified for each subsystem at this point. Figure 3.2-1 provides an example of this initial step. (Step 4 handles the case where stakeholders or systems don't map to - or are not addressed by - the National ITS Architecture)

2. Create a top-level physical architecture based on the identification of major information flows (architecture flows from the National ITS Architecture) between stakeholders that are consistent with the existing systems and the regional ITS improvement plan. This can be accomplished in several ways, depending on the extent of existing ITS services and information sharing and the level of detail and organizational approach of the regional ITS improvement plan. Two potential ways to do this are:

   (a) Look at the relevant interfaces contained in the physical architecture to determine and document the architecture flows which roughly correspond to the regional ITS improvement plan. Combine these into a single representation.

   (b) Determine which market packages most closely represent the existing ITS situation and the regional ITS improvement plan. Use the market package diagrams to identify and document the most relevant subsystems, architecture flows, and important external interfaces. Combine and consolidate these diagrams into a single view.

3. Reevaluate the physical architecture carried over from the previous step. Delete or modify the portions of the National ITS Architecture (information flows, subsystems, or external interfaces, or functions) which upon further review don't apply to the region or are not consistent with the regional ITS improvement plan.

4. Incorporate any auxiliary specific local requirements or issues (information flows, subsystems, external interfaces, or functions) which are not addressed by the National ITS Architecture that exist or are a part of the regional ITS improvement plan.

5. Add detail or create diagrams that show the interactions and information exchanges of specific agencies within the region, in accordance with the operations requirements or concept of operations (roles and responsibilities) decided upon. (See 3.2.3 for more discussion of operations requirements.) Figure 3.2-2 provides an example of this step.

6. Document the major functions carried out in each subsystem.

Useful National ITS Architecture Documents: Logical Architecture, Volumes 1 and 3, Physical Architecture, Implementation Strategy, Cost Analysis

3.2.3 Operations Requirements

A critical part of implementation planning is the identification of operational requirements of the planned systems prior to implementation. Development of operational requirements requires forward thinking by agencies and service providers. Issues to be addressed may include: the roles and responsibilities of the different organizations, development of a concept of operations, identification of funding requirements, interactions during incidents or special events, and other operations and maintenance (O&M) considerations. This includes establishing requirements or agreements on information sharing and traffic device control responsibilities and authority (e.g., deciding if back-up control capability is desired given a loss of power or failure condition). These decisions will be factored into the regional architecture and will also flow-down through ITS deployment projects as they are phased in.

Because many ITS services and strategies involve communication and coordination, this step of planning for operations cannot be overlooked. In the case of ITS, much more is involved than just thinking about how an individual project is to be operated and maintained (by a single agency) after it is constructed. The importance of this planning is that a shared operational concept will be established that will facilitate the future working relationships between agencies and service providers.

The concept of regional transportation management can significantly impact the O&M activities of agencies and traveler information service providers. In some cases, it may increase operations and maintenance costs with the introduction of additional equipment and new technology. Increased costs may arise from the need for additional staff (or staff training) to operate the systems and additional (and potentially more expensive) maintenance for these new systems. The increased investment in operations and maintenance should eventually result in lower user costs due to improved system efficiency.

Identification of O&M requirements is crucial to the success of a project. The development of O&M requirements should involve those most knowledgeable about these issues, namely the personnel responsible for day-to-day operations and maintenance activities in the different agencies.

The Theory of Operations document can be used to illustrate the sharing of information between subsystems which is relevant in determining the working relationships needed between different agencies in order to implement the planned ITS improvements. This type of information can be invaluable in developing an overall concept of operations.

Useful National ITS Architecture Document: Theory of Operations

3.2.4 Linkage to the Transportation Plan

Implementation planning describes how a regional transportation management system will evolve. Vital to this characterization is how to package this gradual evolution in terms of projects and funding. The transportation planning process addresses the relative priority of investments in various transportation improvements, and it is imperative that relevant information from implementation planning be considered as part that process. Potential opportunities for leveraging resources, such as adding ITS surveillance and communications infrastructure to facility reconstruction or capacity expansion projects already planned, should also be explored.

It is important that reasonable estimates of the benefits and costs of specific ITS or transportation management improvements be provided so that these improvements can be considered fairly as part of the transportation planning process. The National ITS Architecture development effort produced information that can assist that process.

3.2.4.1 Benefits

The National ITS Architecture also contains material that identifies the likely benefits of integrating market packages and the context where these benefits may accrue. Tables showing the likely benefits and context where benefits may accrue for each market package are provided in the Performance and Benefits Study and the Implementation Strategy. Additional resources for ITS benefits information are listed in the References section.

Useful National ITS Architecture Documents: Performance Benefits Study, Implementation Strategy

3.2.4.2 Costs

As a tool to assist in the estimation of costs, the National ITS Architecture documentation contains a series of spreadsheets. Although these should not be used for actual project cost estimation purposes, they are useful to help agencies estimate ballpark costs for planning purposes. Examples of how these spreadsheets can be used to estimate costs of market packages were provided in Section 2.6.

Useful National ITS Architecture Document: Cost Analysis

Financial Opportunities and Constraints

Linkage with the capital plan will also require analysis of revenue sources and benefit streams associated with the regional system implementation. This step is where the potential role for public/private partnerships can be considered and weighed.

The physical architecture identifies the interconnections among different transportation subsystems and can assist agencies in determining common components of systems. This may point out opportunities for sharing resources. Common examples include a communications infrastructure, surveillance devices, and traveler information systems. An individual agency may be able to reduce costs by sharing these components while minimizing capital and operating costs.

Useful National ITS Architecture Document: Implementation Strategy

3.2.5 Time Phasing

Because it is unlikely that an entire regional transportation management system will be deployed under a single project, implementation planning should also address prioritization and time phasing of projects. This can be based on a number of criteria such as political issues, cost, amount of impact, and user visibility. The first components that should be implemented are generally those that:

- Fulfill common functions such as surveillance and communications
- Have the potential to provide early visible benefits to the user such as reliable traveler information

Projects need to be defined in sufficient detail so that benefits and costs can be reasonably estimated. Other elements of the candidate project definition include identification of funding sources, both for capital and recurring operations and maintenance costs, and identification of potential implementation impediments.

3.2.6 Regional Technology Agreements

A review and assessment of existing and emerging technologies should also be conducted to allow agencies to make good choices among the different technology or deployment options. For example, regional choices on technologies or standards may be required for the telecommunications infrastructure, electronic toll tags, signal controllers and interfaces, traveler information message formats, electronic fare media, and specialized mobile radio systems.

Standards should be identified to provide for interoperability of systems and interchangeability of components. Identification of standards should consider the current status of ITS standards development activities, and determine how and when these can best be incorporated into the designs of the regional system and individual projects. Establishing regional agreements prior to the issuance of national standards allows for compatibility of systems to be realized sooner at the local level. After national standards are completed for various interfaces, the regional stakeholders are likely to want to eventually transition to them (although not all interfaces will be the subject of a national standards activity and regional standardization may be sufficient in some cases). The benefits of using national standards include:

- Compatible and interoperable ITS deployments
- Lower deployment risks, thus stimulating public and private interest in ITS
- Reduced product costs by providing an incentive for multiple suppliers
- Widened markets for suppliers

Standards development is an ongoing process. As agencies and vendors become educated in the implementation of standards, the risk and cost associated with system integration should be reduced.

It is sometimes difficult to identify which standards exist and are relevant. The following four-step process is recommended for choosing the appropriate standards:

1. Develop the regional architecture. Major interfaces and the interface requirements will be defined as part of this step.
2. Review publicly available information on ITS standards to determine the status of standards work that is of interest. (See Section 5 for more details on where to find this information).
3. Talk to the organizations involved in relevant standards work, such as AASHTO, the Institute of Transportation Engineers, the Society of Automotive Engineers, ITS America, and other standards developing organizations.
4. Select the standards that specify each of the major interfaces of interest.

Regional technology agreements may also specify design options to be followed. Tables provided in Section 4.5 of the National ITS Architecture Implementation Strategy outline some of the major design options for each of the market packages.

Useful National ITS Architecture Document: Implementation Strategy

3.3 Project Deployment

Regional concept and implementation planning leads to project deployments that fit within a regional transportation management context. Material in the National ITS Architecture documents also provides agencies with insight on deployment issues, as discussed previously in Section 2.

Project deployment includes detailed design development, procurement, and implementation. Deployment may also be linked with other capital improvements, such as including conduit for communication links in roadway re-construction projects. Some helpful project deployment hints are provided in Section 4 of this document.

3.4 Evaluation

Evaluation involves measuring and documenting the quantitative and qualitative impacts and benefits that are derived from the proposed implementations. An ongoing evaluation process should be developed that allows for assessment of progress against the measures of effectiveness developed in the concept planning stage.

It can be very difficult to measure quantitative benefits of many ITS services and improvements because of the uncertain nature of travel demand on any given day at any given time. Consequently, qualitative and anecdotal measures can be very useful in illustrating the benefits of many ITS services, especially to agency decision-makers and political representatives.

Useful National ITS Architecture Documents: Performance and Benefits Study, Evaluation Results

4. Lessons Learned / Best Practices

This section provides some advice from experience on how to best develop and implement advanced freeway and incident management projects from agencies that have developed and implemented ITS projects, or are currently developing or implementing ITS projects. Information contained in this section was derived from phone interviews, focus group sessions, site visits with agencies, and from the experiences of several consultant organizations. The lessons learned and best practices in this section are not intended to be guidance or direction from DOT, but are provided as helpful information.

4.1 Teamwork and Coordination

Teamwork and coordination, involving all stakeholders, plus selecting and empowering the right kind of program manager and staff, may very well be your key to success.

Teamwork & Coordination may be your Key to Program Success

4.1.1 Regional Coordination

In order to be most effective, advanced freeway and incident management systems must be cooperatively defined and operated in a coordinated manner with other transportation operating agencies in the same and neighboring jurisdictions, with emergency management and services providers, and with other entities whose operations are impacted by operation of the traffic management system. This will call for use of the team approach, involving as many of the stakeholders as possible, in the development of the program and individual projects. The team approach is needed for a building of trust and working relationships throughout the process, all of which must be carried forward into the actual operation of the system if full benefits to the public are to be realized.

Some key lessons and best practices:

- Include all stakeholders in regional planning and project development phases of ITS programs.
- Involve a regional planning organization with a decision making body and technical support committees.
- Direct focus at current and potential ITS projects rather than at broad ITS themes.
- Involve police and other public and emergency services safety agencies early in the planning/development process.
- Visit traffic operations centers in other regions, particularly freeway traffic management centers, to learn about the benefits of ITS projects. Use the information gathered to get buy-in from agency decision-makers and other

stakeholders. Even better, get the decision-makers to make the visits and see the benefits for themselves.

- Address the region’s needs in ITS projects, rather than just deploying technology for technology’s sake.
- Perform public outreach. Emphasize the cost related benefits of ITS projects to justify ITS to the public.
- Share the cost of ITS project staff, facilities, and equipment with other ITS stakeholders in your region. The term for this is “Resource Sharing.” Resource sharing works because many ITS benefits are also shared, particularly those derived from interagency or interjurisdictional ITS integration.
- Consider the time required to get a Memorandum of Understanding (MOU) developed and signed by all major stakeholders. Legal issues take a considerable amount of time to resolve.

It is important to appreciate the fact that ITS deployment programs differ in many respects from the traditional highway and street projects which state and local DOT’s have for many years developed, constructed, and maintained. It follows that the *process* through which ITS programs are developed must also differ from that which has been used in the past.

An open development process, involving all stakeholders, featuring the team approach and leading to the building of consensus, trust, and good working relationships, is essential.

This building of consensus, of trust, and of working relationships will all take special effort on the part of those developing the program; it will consume more staff time and will significantly lengthen project development time. However, it is essential for success. As noted in Sections 1 and 2, use of the National ITS Architecture tools can help to offset the additional time by savings in staff time and project development time.

4.1.2 The Program Development Team

It is important that support for freeway and incident management programs be built and maintained as the development process moves along. This support will be vital as various approvals are sought including approval to include the program as a part of the Regional and State Transportation Improvement Plan, approvals for funding, and approvals of individual projects. That support will also be vital as the program moves forward into procurement, through system integration and into actual operation, for highly successful operation will only be achieved through a spirit of cooperation and accommodation, through the coordination of activities of the many operating entities. And the best way to develop and to maintain that support is through a continued involvement of the many stakeholder entities throughout the entire development process. This group of stakeholders can be referred to as the Program Development Team.

Develop a broadly based Program Development Team involving as many stakeholders as possible. Keep the Team actively involved throughout the development of the program; let the Team share in the ownership, the responsibilities, the credit associated with the program.

The role of the team in the development of the program is a critical consideration. Share with the team throughout the program:

- Let the team members help in shaping the program;
- Let the team members be a part of moving the program forward;
- Let the team members feel a sense of ownership of the program and a responsibility for the program; and
- Let the team members share in taking credit for the successes of the program.

Some key lessons and best practices:

- Involve the stakeholders throughout the program development process, although staff should become more technical or more detail oriented as work progresses.
- Form separate, but coordinated groups within the Program Development Team to address planning, design, procurement, and operations. High-level Team members may provide steering of the program while more technically oriented staff from the same agencies will be needed to participate at more detailed levels.
- Carefully define group charters and objectives to sharpen group focus and thus heighten productivity and speed results.
- Share project successes and credit for successes with all members of all groups.

4.1.3 The Program Manager

Many operating agencies that have successfully deployed and operated ITS programs have attributed much of their success to a common key factor, the presence of a “champion.” The champion is a person who fully understands the benefits that can accrue from the program and is fully committed to the program. He or She is one who is willing to “go the extra step” to see the program fully deployed and operational and is skilled in convincing others of the value of the program.

Some key lessons:

- Insure continuity of project management.
- Select a well-qualified program manager.

The program manager should have a background in transportation engineering and in traffic management, plus knowledge of incident management and emergency services. Training in systems engineering and program management disciplines would be beneficial. He/she should possess both communications and people skills, as well as being computer literate. It is important that the champion hold a relatively high position within the organization, and be respected both within and outside of the organization.

Assign a well-qualified "champion" as Program/Project Manager.
Program management continuity will be crucial to program outcome.

4.1.4 Staffing the Program

Selection of the key staff to support regional transportation planning and to perform the project development work is very important. These staff must have basic transportation management experience, some knowledge of incident management, and may be trained to achieve a basic understanding of National ITS Architecture application.

Some key lessons and best practices:

- Address staffing issues early. Prior to the start of an ITS project, ensure that adequate, technically qualified staff are available to the project manager.
- Involve the agency that governs hiring as early as possible.
- Do not underestimate the time requirements involved in the training of public agency staff.
- Involve operations and maintenance personnel in all phases of ITS project planning and deployment so that their roles, responsibilities, and needs are accurately defined and addressed.
- Include procurement personnel at the beginning of the project. Procurement is as important a phase of the project development as the design and build phases. Involve legal staffs early in the process to prevent fatal flaws such as non-conformance with federal, state, and local laws and regulations.

4.2 Project Development Process

Fundamental steps used by transportation agencies in the formulation and implementation of projects include assessing problems or needs, the search for and selection of a solution, design of the project, and finally, the funding, procurement and implementation. These are the same process steps described in Section 2.

4.2.1 Assessment of Needs or Analysis of Problems

In developing any ITS project, one must keep in mind the age-old axiom - Let the problem drive the solution.

Some key lessons and best practices:

- Gaining consensus on the project definition, user needs, and user requirements can take several passes.
- Consider use of focus groups to help determine users, user needs, and technologies involved.
- Consider use of peer review groups for ensuring clarity and completeness of needs assessments.

A thorough analysis of the operational problems being experienced needs to be made early in the process. The exact nature, the magnitude, and the extent of each problem; and the conditions that are causing the problems, need to be fully understood before even beginning to consider the solutions.

Use a needs-driven approach in developing the program and always LET THE PROBLEMS DRIVE THE SOLUTION.

This needs-driven approach becomes particularly important in ITS projects. It has been noted all too frequently that, in the consuming drive to bring high technology systems to the transportation scene, the process has been reversed, resulting in an approach in which one finds high technology “solutions” in search of a problem. This can result in a high cost project that falls short of doing the job that needs to be done.

4.2.2 Identification of Solutions

As a first step in the development of solutions, key individuals involved with the program should become thoroughly knowledgeable on what solutions (generically) have worked for others. It is also important that staff be aware of those which have not worked and why they have not worked. There are several ways to do this and possibilities include:

- Communicating with other agencies who are operating ITS applications.
- Attendance at Federal Highway Administration and Federal Transit Administration courses.
- Reviewing the literature.
- Attendance at seminars, workshops and conferences covering the subject.
- Seeking advice from your FHWA Division or FTA Region Offices.

Courses may be provided as part of the ITS professional capacity building program: see the FHWA’s Office of Traffic Management and ITS Application web page at URL <http://www.fhwa.dot.gov/hst/pcb/itscord1.htm>. The PCB Program's goal and main emphasis is on developing awareness of key aspects of the ITS program in FHWA, FTA and other public sector transportation professionals. This professional capacity building ranges from short-courses and hands-on experience to intensive training.

Whatever the means, getting key project staff “up-to-speed” on ITS applications to transportation management problems is a critical activity that must be carried out.

The project staff that are knowledgeable of ITS solutions to transportation management, including incident management, problems must be engaged in identification of the more favorable solutions to the problems being addressed. From this list of solutions, the trade-offs of costs and benefits plus any other impacts and considerations such as impact on maintenance and operations staffing and costs, of the solutions should be addressed and recommendations prepared. The recommendations coming out of this activity will be a key input to transportation planning process, see Section 3.

Some key lessons and best practices:

- Act to ensure that key staff are up-to-speed on ITS applications. The first verbal contacts for further information on this should be directed to your FHWA Division or FTA Region Offices.
- Consider operational and maintenance impact as well as capital cost and potential benefits.
- Consider using peer review groups to review and comment on the list of solutions and on selection of the solution that best fits the region’s needs.

4.2.3 Planning and Design of the Solution

Detailed design of the project should proceed based upon those system elements which have been defined in the solution definition and analysis. During the project design phase, as the full implications of using specific hardware/software systems come more into focus, it may be necessary to rethink some of the decisions reflected in prior planning. It is fully appropriate - in fact, it should be viewed as a responsibility, to make trade-offs, and appropriate changes in the project at this point in the project development process. Some of these trade-offs will be in freeway and incident management system configuration alternatives as described in Section 2.

There are two general approaches which have been taken in deploying transportation management systems, and thus, in the defining of the project to be implemented:

- The full deployment approach in which the entire freeway traffic management and incident management system is deployed under one construction contract, or one design-build contract.

- The staged project approach in which separate contracts are awarded for the construction of a number of stand-alone subsystems, which when completed, will comprise the comprehensive transportation management system.

The “Full Deployment” procurement approach requires funding for the deployment of the transportation management system in its entirety under one contract. This approach will produce the entire system as a whole, rather than as the combination of a series of individually contracted sub-systems. With one contractor having responsibility for the entire system, the integration problems should be minimized, thus helping to ensure interoperability. The components of the system must be made to work together before the contractor’s performance is accepted and full payment is made, so there is the potential of the contractor to play down the importance of those problems associated with the integration of complex systems. However, with carefully planned progress payments tied to specific accomplishment milestones of contractor performance, the pressure on the contractor is reduced somewhat. Higher levels of annual funding, always difficult to secure in today’s environment of funding shortfalls, are required for this project approach. The operating staff is also suddenly faced with the operation of the entire system all at once and there is no time for staff to grow into that level of operation through operating smaller, less complex sub-systems. Advance arrangements need to be made for operations and maintenance training.

Under “Staged,” “Incremental,” or ‘Evolutionary” approach, a series of projects, each consisting of a stand-alone subsystem capable of delivering benefits, are constructed under separate contracts over a period of time. Each subsequent sub-system is integrated with those that have preceded it, evolving into the comprehensive system. One of the major areas that must be addressed up front is definition of the communications facility or capability that will handle the long-term needs of the transportation system. The greatest risk of the staged project approach has to do with those problems associated the integration of new systems with those which are already on-line, and with the assignment for accountability of that function. When two subsystems can’t be integrated and one or both subsystems have to be modified, the costs may increase substantially. However, there are advantages. Available funding levels are less of a problem, as projects to match available funding levels can be spaced out over a period of time. There is the opportunity to select "winners," those projects on which there is a high probability of success, as early projects with very visible benefits. Systems come on-line at a more manageable pace. There are the advantages associated with evolution, including:

- Building staff skills, evolving operational procedures, and building inter-agency working relationships can be accomplished along with the development of the system.

- Concepts of ITS freeway and incident management are allowed to grow and mature as the overall system evolves.

- Traffic management measures are introduced to the public in smaller, perhaps more acceptable, increments.

Some best practices for defining the project:

- Use an open architecture based on the National ITS Architecture and ITS standards as the basis for design.

- Several agencies have concluded that a process of phased implementation for ITS projects is optimal. It may not be necessary to deploy all the planned technologies, functions, and equipment needed for your new freeway and incident management system initially. Incremental deployment will allow agencies to manage budget and staffing level growth. For a phased implementation the system must be designed initially for the addition of future functionality and incremental expansion.

- Be realistic about your capabilities and get help accordingly. Use integrators and consultants to assist in the project.

- Conduct a communications study to make sure that future requirements are accommodated by the system design (i.e. number and type of devices: computers, controllers, cameras, variable message signs, etc.). Communications analysis can easily be overlooked when most of the design discussions center on the central computer / traffic management center needs and field element considerations. Overlooking this area can be a costly mistake for replacement of inadequate communications.

- Build only what you can realistically maintain. During the design and build phases of the project, maintain realistic maintainability/reliability expectations.

- Use peer review groups to review the project design.

- Do not rush the project planning, requirements, and specification phases. To avoid delays during the development and installation phases, define the project requirements clearly. Also design to the needs that have been defined. Always keep the needs developed and approved through the planning phases sharply in focus.

- In order to ensure the reliability and functionality of enabling technologies, it is recommended that the agency developing ITS applications fully investigate previous applications of candidate technologies in real world applications. These investigations should include discussions and/or site visits to agencies that have previously deployed the technologies. It is also important that these investigations be carried out independently of any vendors.

- Performance standards must be defined for all system components.

It is essential that ITS systems be designed to:

- Solve the transportation problem.
- Provide for compatibility of operation with a variety of systems being operated by other transportation-related entities.
- Provide for interoperability with those other systems.
- Be readily modified and/or expanded in the future.

4.2.4 Funding, Procurement, and Implementation

4.2.4.1 The Schedule

The schedule must be well thought out, be realistic, clearly show task inter-relationships, and be in a form that can be easily communicated and understood. It must have the commitment of the project team. It should be used on a continuing basis as one of the most powerful tools in managing the project. All reasonable steps should be taken by all parties to adhere to the schedule. It should be up-dated and adjusted when slippage does occur.

Some key lessons and best practices:

- Do not adopt an optimistic schedule.
- Define frequent and realistic milestones to use in assessing progress against the schedule. This must include clearly defining milestone and task precedence relationships.
- Unambiguously define all milestones.
- Define milestones so that reaching each milestone is clearly identifiable and not reaching each milestone is also clearly identifiable.
- Make reasonable efforts to keep the project on schedule. However, never cut schedules for reviews of design documentation, for preliminary and final design review presentations by the contractor, for system integration, or for thorough testing, in the factory, at the first field site and at every field site. When needed to preserve these critical activities, extend the schedule.
- The schedule, and each change to it, must be fully coordinated so that all responsible work areas contribute to development of the schedule and then buy-into and commit to the schedule.

4.2.4.2 Funding the Program

Obtaining funding for the project is one of the most critical responsibilities of the project manager and his/her higher management. It is essential that he/she "think funding" from the inception of the program, seeking out every opportunity to secure funding from a variety of sources for the various elements of the overall program. One goal should be to secure funding from a number of sources—the more the better—for the commitment of funding assures that there is a support for the overall program from that funding source. The commitment of funding from private sources, through public/private partnerships or other arrangements, further strengthens the program insofar as competing for funds from public sources.

Some key lessons and best practices:

- Commitment of capital funding as well as operations and maintenance funding from private sources, through public/private partnerships or other arrangements, thus leveraging the public funds, further strengthens any ITS program insofar as competing for funds from public sources. Also, the higher the federal match and the private partner investment, the more likely the project will be included in the capital improvements program.

- Share your funding experiences for design, construction, operations and maintenance.

- Share your experience using Federal-aid funding for operations cost and how to work with your metropolitan planning organizations (MPOs) to get their support.

- Shortages of funding are common, as a result of stiff project competition (primarily traditional non-ITS projects); budget cuts; capital vs. operations and maintenance budgets; and operations and maintenance cost increases.

- Maintain a realistic assessment of funding.

It is important that the project get into the programming process as early as possible in the project development phase, in order that funding will, in fact, be available at the time the project is ready for construction. While many ITS projects in the past were funded without going through the Transportation Improvement Planning (TIP) process (since they were funded as under a research or operational test environment), steps should be taken to have the project included in the TIP, in order to ensure eligibility for funding. Projects need to be entered into the programming stream to obtain funding from other sources.

There are a variety of funding sources to cover various elements of the ITS projects that support traffic and incident management. Most agencies develop funding packages that include funding from several sources. These types of projects may be eligible for federal funding, and for state transportation funds. The Maryland State Highway Administration and the Arizona DOT obtain Congestion Management Air Quality (CMAQ) funds and Interstate Discretionary funds to cover capital costs. Funding for staff generally comes from state operating funds. Additional funding sources include other ISTEA funds, local sources, bonds, and toll revenues.

Develop a broad-based funding package, with funding coming from as many sources as possible.

It is also important to keep in mind that ITS projects carry with them the obligation to operate and maintain the systems. Thus, it is important to not only obtain capital outlay funding, but also to secure the commitment for covering the on-going operating and maintenance costs.

Identify funding sources, and carry projects into the programming processes at the earliest possible stage of project development. Secure approvals for staffing levels to operate systems, and for funding to cover other on-going operating and maintenance cost, such as contract maintenance.

4.2.4.3 Agency / Contractor Interaction and Other Issues

Many agencies strive to keep the contractor "at a distance" which would work well in a perfect world where requirements are perfectly described and understood and where the contractor's design is perfectly described and understood. Lacking this perfect world, developing a cooperative working relationship between agency and contractor is most likely to yield a system that meets agency requirements. In such a relationship, it is appropriate that rules be established to limit information going to the contractor from agency staff and other agency representatives to "interpretations of the requirements," and within the contract scope. Included must be the admonition that only through contracting officer direction may the scope of the contract be changed.

Some key lessons and best practices:

- Don't simply take a vendor's or contractor's advice or word on the capabilities of a system or piece of equipment. Ask them: "Has the (system/software/equipment) been used in a freeway and incident management system before? Has the (system/software/equipment) been used to perform this (task/function) before?" Be sure to obtain references as to where these applications were and what agencies were involved and then talk to those references.

- Make sure the company from which you are purchasing services or equipment from is financially sound. Check business and technical references. Talk to others in the field who have contracted with the company to do what you are planning to do. Expect some criticism of the contractor, since design reviews always identify some changes in interpretation of requirements thus impacting scope of the contractor's work. Keys are—first, was the list of changes reasonably small, second, was the contractor cooperative and reasonable, and third, did these seem to be honest misinterpretations of requirements.

- Maintain focus on the system's final configuration definition. Keep the system developer's focus on the requirements of the final product, not just the next deliverable.

- Allow sufficient time for a comprehensive review of draft and final versions of specifications and requirements.

- Take the time needed to review important project requirements. For larger projects, allow the contractor/equipment vendors at least two passes (one draft, one final) to develop the user requirements and the equipment and software specifications. For smaller projects, one pass may suffice. Arrange in the contractor's work statement for audio/visual presentations of the draft and final designs to agency staff, plus other agency representatives and project stakeholders. This is helpful in identifying requirements misinterpretations.

- When significant amounts of software development are involved, arrange to have one or two key staff and expert software engineer representatives sit in on the contractor's internal software design walk throughs, since these cover how the system will work in some detail and may highlight misinterpretations.

4.2.4.4 Managing the Program

There are many lessons that have been learned on ITS projects and on other kinds of projects, including those from program management efforts of other civil and defense agencies. Although most ITS projects are much smaller in scope than most defense projects, many of the lessons apply. Most of the system engineering tools that other agencies have used are beyond the scope of this document, but guidance on courses or seminars that describe application of those tools to ITS projects is available from the FHWA Division or FTA Region Offices.

Some key lessons and best practices:

- Look for success stories in the ITS field prior to starting your ITS project. Learn from projects related to what you are trying to do—what are the benefits? Was it cost effective? Also check out the benefits reference documents. This will help you to support your project as it develops.

- Provide upper management and decision makers with real examples of successfully deployed ITS projects. This is a way for agencies to overcome resistance to ITS technologies. Example projects should relate to the unique transportation problems in your region.

- Use the design/build process to get systems operating early whenever appropriate. However, it is important to separate the design aspects of the project from the build by thorough review of all design aspects. The review time required for a design should not be underestimated.

- Manage project and system expectations. They need to be realistic and achievable with available funding, time (schedule), and staffing.

- Exceeding the costs estimated for software development is highly probable and a major problem in the industry. Cost overruns are common in ITS projects. Agencies need to be prepared for these overruns by developing contingency plans. Contractors can only base realistic software development cost on detailed and accurate requirements and specifications. The lead agency should maintain a contingency fund for handling changes in scope.

Ë Use technical proposals and preliminary and final design reviews to achieve compatible agency and contractor interpretations of requirements as early as possible. Differing interpretations will yield false starts and wasted effort, time and money.

Ë As unanticipated problems occur, the schedule slips, staff once available becomes unavailable, budgets appear inadequate—a few words of advice:

L Take a step back and take a look at the big picture to reassess where the project stands. Back away from trying to cope with numerous details and topics with which you may not be completely familiar.

L Revisit your project plan. To help bring the project back on track, all parties involved will need to be honest about achieving project expectations, and about assessing what can be realistically accomplished with available resources.

L Be reasonable about deliverables, schedule, scope, and requirements.

L Focus on the system features that will bring the most benefit. Consider dropping less significant aspects of the project.

L Focus on what has been accomplished so far, rather than on how much is left to do. Other staff may need reassurance. Positive motivation can be very helpful to your team, and help you get through a crisis.

L Create an environment that encourages solutions, rather than focusing on problems. Establish an environment in which your agency, the equipment vendors, and contractors can cooperate to complete the project successfully.

Ë Share your successes, and share credit for your successes.

Ë Learn and share lessons from all projects. Create an environment where engineers from different backgrounds and projects have an opportunity to share their experiences with each other—begin a “brown bag” lunch program or project/technologies discussion group.

Ë It is critical that initial ITS project deployments provide immediate, visible and significant benefits. Failure to do this will make it harder to secure funds for future ITS projects.

Ë Reduce the risk of failure by deploying ITS projects incrementally and by using proven technologies.

Ë Document control is very important. Track and control project documentation. Use a numbering scheme, such as PROJECT-TASK-YEAR-DOCUMENT NUMBER-REVISION LEVEL.

- Share your funding experiences for design, construction, operations and maintenance.

- Share your experience using Federal-aid funding for operations cost and how to work with your metropolitan planning organizations (MPOs) to get their support.

4.2.4.5 System Integration and Testing

Being very thorough in the integration and testing of your system will be as important, perhaps more important, than anything else you do on the project, including writing complete and accurate specifications. System integration and testing will be needed at different levels. During development, integration and test will be accomplished the first time and must be very thorough, testing against every requirement. This testing may include rigorous testing, analyses and demonstrations. Acceptance testing in the field need not test every requirement, but must ensure that the deliverable is acceptable.

Some key lessons and best practices:

- Integration of existing/working technologies is hard enough without introducing new and untried technologies.

- Systems can be built incrementally; however, any necessary communications equipment needs to be in place for integration with prior and future increments.

- Integration needs to be done in a controlled environment (e.g. design or factory acceptance tests) to isolate problems and system bugs. Interfaces with some devices may have to be emulated for early integration efforts.

- Do integration in steps—add one component at a time. Do not wait until the end of the project to integrate all of the system components, since it would be extremely difficult to isolate problems. Integration and testing can easily take 30–40% of the time and resources of a project.

- Take the time to thoroughly debug and test a few units in the field prior to deploying a large number in the field. Require contractors to successfully conduct acceptance tests on each major deliverable, witnessed by the agency's representatives prior to acceptance by the agency.

- When changes are made in some area of a design, keep in mind that there may be desirable and undesirable consequences of the change that may ripple through the design, and testing must ensure that the device, unit, or subsystem still functions properly after the change.

- Perform operational and maintenance training early. Use those trained staff in hands-on roles for operational and maintenance testing, particularly final development test in the factory and final acceptance test at the first field site. This must be written into the contract since contractors will otherwise not allow non-contractor staff to touch their equipment.

4.3 Procurement and Contracting

Traffic management agencies face many impediments in the procurement and contracting of developing projects, as procedures and controls and measures which have been put into place over the years for highway construction projects have had to be accommodated. However, there is some relief for these impediments. This section sheds some light on the more common problems that have been experienced, and some of the solutions that have been developed.

Project team members should work together to select the most appropriate procurement mechanism, contracting lead agency, and contracting approach for any particular project. Decisions relative to these points, as well as a number of procurement related issues, need to be made early in the project development process since many facets of the project will be impacted by these decisions.

4.3.1 Autonomy in the Procurement Process

In some agencies, it has been the practice to clearly separate the procurement function from those who will use the goods or services procured. This autonomy in the procurement process is seen as providing certain assurances relative to the proper expenditure and management of public funds. However, because of the technical complexity of most ITS systems, and the need for these systems to be interoperable, technical and operational advice is critical in making wise procurement decisions.

Transportation management agencies should balance the need for autonomy in procurement with the obvious need for those with the technical and operational knowledge of ITS systems to participate in the procurement process. A sufficient degree of autonomy can be maintained while still involving technical staff, by adopting a team approach to procurement, which would include technical advisers and budget and procurement personnel. By bringing both sides together, each can gain a better understanding of the knowledge each brings to the discussions.

It is crucial in ITS procurements that technical/operational, budgetary, and management elements be involved in proposal evaluation with each presenting its findings to a selection board. Bids from contractors that are not judged responsible companies able to perform or with technical proposals that are not technically acceptable should be rejected.

This will allow the technical advisers to make recommendations on the extent to which or even whether the types of technology and systems available will meet agency needs. It will also allow the procurement specialists to outline budget, financial, and procurement restrictions that may impact how the type of technology or service is to be procured.

4.3.2 Selection of the Contracting Approach

The selection of a particular contracting arrangement for deploying ITS traffic management systems is critical to the successful deployment of these systems, and, ultimately, to the successful operation of these systems. Three contracting approaches to the deployment of these systems, discussed below, have been used; the use of each has met with varying degrees of success. See also a paper on innovative contracting for ITS projects [Innovative Contracting Practices for ITS, April 1997] and another paper on procurement regulations and contracting options [FHWA Federal-Aid ITS Procurement Regulations and Contracting Options, August 1997] both available on the FHWA ITS web page . This paper, available in hardcopy from NTIS or electronically from the Turner Fairbanks Highway Research Center web page, is a valuable resource. Figure 1 of that paper identifies four basic contract types, their possible application, and their approval requirements. Three of those approaches are discussed below.

Conventional PS&E/Contract Bid Approach

In this approach, the designer develops specifications for both software and hardware, and these are included in the PS&E (Procurement Specification and Estimate) package and RFP (Request For Procurement). A contract for the construction, hardware, and software to deploy the system is then let in the manner of a conventional highway contract. This contracting approach may be appropriate for procurement and contractor installation of field devices and hardware. However, for design, development, integration and system engineering services, this approach has resulted in some problems in the past. Hardware/software incompatibilities have arisen, and these systems have not performed as anticipated. In some cases, major modifications in hardware and/or software was called for in order to produce working systems. Resolution of issues relative to the accountability for these deficiencies, and of the responsibility for the development and deployment of corrective measures have proven to be particularly difficult in many cases. In general, this approach does not work well for technology acquisition.

System Manager Approach

Under the system manager approach, a consultant is engaged to develop the software and hardware specifications for the freeway and incident management system, and to produce a PS&E for the project. Contracting for the system manager’s services falls under the Engineering and Design Services contract category which includes services like program and construction management, engineering, design, and surveying. Using the PS&E developed by the system manager, a contract for furnishing and installing hardware, and for other required items is let, using traditional contracting procedures as in the contract-bid category of contracting. Here, a key difference comes into play: the software/hardware consultant’s responsibilities carry into the deployment phase of the system under this approach. The consultant is responsible for the final design and development of software and for integrating it with the hardware as it is installed, and for providing documentation and training to operating staff in the use of the integrated system. Several advantages to the system manager approach have been noted:

- The process includes competitive bidding, with all of its benefits, for the furnishing and installing of hardware, and for facility and electrical construction.

- Access to those developing the system software, and agency control over system development, are greatly facilitated. If the control system hardware is included with the software bid, a hardware contractor who does not produce software could win the bid. The hardware company will subcontract the software to a software company. The client then has very limited access and control over the system development and may not be able to ensure that the system meets its requirements.

- The system manager approach gives the flexibility to incorporate the latest technologies into the system, as well as to provide integration with other traffic control systems which may be operating on other roadway networks. It is important to avoid the low-bid syndrome, where the software is designed to do the absolute minimum required to meet the specifications rather than take advantage of the latest thinking and processes in a rapidly evolving technological market.

Design/Build Approach

In this approach, a contractor is selected based on the contractor's qualifications and an assessment of the contractor's ability to perform followed by competitive negotiation. This single competitive contract is then awarded for design and construction of the project. This differs from the design-bid-build approach in that design-bid-build uses two sequential competitively awarded contracts, the first for design and the second for construction. The design/build approach traditionally combines the procurement procedures employed with the traditional engineering and design services contracts with those used in the traditional construction contracts, and thus embodies characteristics of both. These procedures may include pre-qualification, competitive sealed bidding, and award criteria based on price and other factors. It may be useful to require separate detailed technical proposals and cost/business proposals and evaluate technical proposals first. Then the predetermined selection criteria would include evaluation of the offerors' technical proposals that have been found to be acceptable, by a predefined set of criteria. This approach will provide indications of the each offeror's skills, understanding, and approach to the project. The negative is that the project requirements must be spelled out in the RFP so that the offerors can respond to them.

The design/build approach relies on the contractor to develop a design and then to build the project. The agency's role is to monitor the contractor's work. Generally this has worked for roadways and structures. However, it may have significant problems when applied to technology acquisition depending on contract type (e.g., fixed price or cost type) and the nature of the relationship between the agency and contractor. If the agency has a hands-off approach to contract management, the contractor may design and build much of the system based on incorrect interpretations of requirements. Some of the work may be found to be unacceptable. Partnering of the agency and contractor so that requirements are properly interpreted and the design is reviewed by agency representatives and found acceptable, before construction and implementation work proceeds, can lead to positive results. However, if the entire contract is a fixed price type, the contractor has an incentive to interpret requirements, produce a design, and build the system to minimize the contractor's cost. A way to address this issue is to have the agency more directly involved in the clarification of requirements during contract performance. This, in turn, may increase the contract scope. Also, if the contractor subcontracts the software to be designed and built by another contractor, there may be lack of visibility into the software development process. This is likely to result in a lack of agency knowledge and control of the software and an unacceptable system.

<u>Other solutions</u>

FHWA established Special Experimental Project No. 14 , Innovative Contracting Practices (SEP-14) to enable agencies to implement and evaluate innovative contracting practices that maintain competition advantages while striving for quality and timeliness. Included under SEP-14 are Experimental Design-Build and Non-Experimental Cost-Plus-Time contracting innovations. Federal-aid funds may be used in design-build contracts when awarded with competitive bidding procedures and subject to FHWA approval under SEP-14.

Give full consideration to the use of the System Manager Approach when deciding upon the contracting arrangement to use.

4.3.3 Procurement Rules and Regulations

Although federal legislative requirements mandating the use of low bid procurements have been relaxed in recent years, many states still require its use for procuring many services and equipment. In addition, it is still the preferred method for acquiring construction services in the public sector. But there can be problems with accepting low bids for ITS systems and devices.

Some key lessons about low bids:

Ë An important problem with low bids: the equipment and software are frequently designed to do the absolute minimum required to meet the specifications rather than take advantage of the latest advances in technology.

Ë The design of the system provided by a low bidder may have many misinterpretations of the requirements with major cost increases for the corrections thus allowing the bidder to bid very low, with later scope increases. Specified requirements must be accurate and thorough. Even then a low bidding contractor will find ways to reduce costs by not meeting requirements or by misinterpreting requirements.

Ë Often systems that are low bid have limited expansion capabilities. These limitations are frequently not discovered until control elements are expanded or modified at a later date.

Ë As upgrades to the system hardware and software are needed in later years, there may be design problems that require very expensive redesign and expansion of the system.

Traditional transportation procurement approaches will usually not provide the flexibility necessary for acquiring ITS projects. In an effort to provide greater flexibility to state and local governments in their procurement procedures, the U.S. Office of Management and Budget established the Common Rule governing grants administration. The rule provides that states will spend and account for grant funds according to their own laws and procedures. While some procurement methods have very specific federal rules to be followed (particularly procurements for architect/engineering services for construction projects), there is considerable flexibility in most other procurement models.

Project team members should work together to select the most appropriate procurement mechanism, contracting lead agency, and contracting approach for any particular project. In selecting the procurement and contracting approach, the most favorable alternatives need to be compared side-by-side listing all pros and cons of each. Decisions relative to project team members, as well as procurement-related issues, need to be made early in the project development process since many facets of the project will be impacted by these decisions.

4.3.4 Procuring Software

Procuring software has always been complex and care must be exercised to control the risks inherent in this activity. There are many important topics to be informed of on software acquisition. As of 1998, U.S. DOT is preparing an ITS software acquisition guidance document. Some of the key topics covered include the following, all of which are important:

- Acquisition approaches
- Consideration of commercial-off-the-shelf (COTS) software with its pros and cons
- Importance of requirements
- Acceptance criteria
- Intellectual property rights
- Schedule issues

The document is built around people, management, and system themes that encourage partnering between the agency and software contractor to ensure understanding and translation of requirements into software.

Using “off-the-shelf” software packages and systems are often touted as low risk, but may or may not reduce risk. Making major changes to an existing software system may be quite difficult. Nevertheless, agencies should familiarize themselves with the different product offerings before issuing procurement documents since it may be possible to meet requirements while saving time and money. A key point— careful consideration should be given to requirements that might involve extensive new software development or extensive product offering changes because of the risk implications.

4.3.5 Procuring Telecommunications

Just as transportation is the backbone of our communities, serving to move people and goods from point to point, telecommunications is the backbone of ITS, serving to move information among detectors, transportation management centers, and field devices. Telecommunications is vital and expensive. A new telecommunications system can be the highest cost item in an ITS deployment project. A telecommunications analysis including the three steps below should support telecommunications decisions:

- Requirements Definition
- Definition of Network Options
- Cost Analysis

The *Requirements Definition* step is the most important. Good decisions can only be made if care is taken during this step of the analysis. The product of requirements definition is a reasonable estimate of how much information needs to be moved from point to point throughout the system in its future fully deployed state. To do this, a rigorous estimation process that focuses on <u>needs</u> rather than <u>possibilities</u> must be followed. This must be supported by an understanding of the types of devices to be installed, where they will be, how many there will be, message sizes and frequencies, etc. Also, the region's plan for locating and communicating among transportation management centers must be understood. Perhaps the most fundamental question in requirements definition is whether the telecommunications system will serve the needs of a single agency, multiple transportation agencies in a region, or multiple government agencies within a jurisdiction or region. The latter two raise issues about ownership and cost participation, but should be considered from a good public policy perspective. The video requirement should be carefully considered. Among the questions to be critically examined: Who needs to see what images? How many images need to be seen at one time? What will the information be used for? Using the video images for commercial television broadcasts may imply need for higher quality than if they are only to be used to view incident scenes. Use of compressed digital video should always be explored, since recent improvements in compression algorithms produce images that approach the quality of full motion video transmissions. If the only use is to view incident scenes, transmission of lower quality, freeze-frame/slow-scan images may be adequate, and require much less communications capacity. For more information, reference the ITS JPO Telecommunications Resource Guide, Tab A, Telecommunications in Transportation, a Summary of Key Issues and Tab B, A Case for ITS Telecommunications Analysis.

The *Definition of Network Options* step involves defining different telecommunications network structures or architectures. For example, the information that needs to be passed back and forth will be very different if processing is distributed rather than centralized. Within the context of these different network structures or architectures, ownership and leasing options should be explored. Thinking broadly in terms of providing a telecommunications service rather than building a telecommunications infrastructure will open the door to consideration of a number of different options, including combinations of leased and owned infrastructure. This may also include resource-sharing opportunities, in which access to public right-of-way is exchanged for a share of the telecommunications capacity being installed in the right-of-way. [Final Report on Telecommunications Shared Resources: Legal and Institutional Issues, 1997].

In the final *Cost Analysis* step, the cost implications of the different alternatives are detailed and compared. Ownership options involve higher installation and maintenance costs, which must be compared against the terms of the available leasing arrangements. Short term leasing deals, on the order of from five to ten years, may enable agencies to possibly obtain more favorable terms in the future, and also enable agencies to take better advantage of technological advances than they typically would be able to with a publicly owned system or longer term leasing deal.

A final but very important point is that typical transportation agency personnel seldom have the experience needed to support informed decisions about these issues. It may be imperative that this knowledge be acquired in the form of new staff or consulting assistance.

5. How Can I Find Out More?

Information on Intelligent Transportation Systems (ITS), the National ITS Architecture, and ITS Standards may be found at the locations described below. Additional helpful references are listed in the References section. You should also know that most Federal reports may also be obtained through:

National Technical Information Service (NTIS), Technology Administration, U.S. Department of Commerce, Springfield, VA 22161

Phone:	(703) 605-6000
Fax:	(703) 321-8547
World Wide Web at	<http://www.fedworld.gov/ntis/ntishome.html>

5.1 How Can I Find Out More About ITS?

Contact the agencies listed below:

First verbal contacts should be to your local Federal Highway Administration Division Office or Federal Transit Administration Region Office. This should include queries relative to areas such as program, technical and policy. This office will work with you to schedule courses, seminars and possibly workshops on ITS topics.

ITS Joint Program Office
Federal Highway Administration, U.S. Department of Transportation, 400 Seventh Street SW, Washington, DC 20590

Phone:	(202) 366-9536
Fax:	(202) 366-3302
World Wide Web at	<http://www.its.dot.gov>

This U.S.DOT ITS web page also provides links to numerous other sources of ITS-related information. With the wealth of information of all types on ITS available via the Internet, it is becoming important that the key staff involved in any ITS activity have access to Internet.

Office of Traffic Management and Intelligent Transportation Systems Applications
Federal Highway Administration, U.S. Department of Transportation, 400 Seventh Street SW, Washington, DC 20590

World Wide Web at	<http://www.fhwa.dot.gov/hst/its.htm>

Turner Fairbanks Highway Research Center
Federal Highway Administration, U.S. Department of Transportation, 6300 Georgetown Pike, McLean, VA 22101

World Wide Web at <http://www.tfhrc.gov>

Office of Mobility Innovation, Advanced Public Transportation Systems Division
Federal Transit Administration, U.S. Department of Transportation, 400 Seventh Street SW, Washington, DC 20590

Phone: (202) 366-4991

Other sources include:

ITS America
400 Virginia Avenue SW, Suite 800, Washington, DC 20024

Phone: (202) 484-4847

World Wide Web at <http://www.itsa.org>

5.2 How Can I Find Out More About the National ITS Architecture?

Where do I look for Information? Again, first verbal contact should be with your FHWA Division or FTA Region Office.

Information on the National ITS Architecture is available at the following locations:

ITS Joint Program Office, Federal Highway Administration, U.S.DOT
Documents that may be obtained from the Joint Program Office include:

- *The National ITS Architecture for ITS: A Framework for Integrated Transportation into the 21st Century*
- *Building the ITI: Putting the National ITS Architecture into Action*

These documents are available on the World Wide Web at <http://www.its.dot.gov>

This site also provides a variety of very informative information, like an overview of what ITS is, a large glossary, several other very informative reports.

Contact your FHWA Division or FTA Region Office to inquire about training:

A three-day training course available from the Federal Highway Administration is *Using the National ITS Architecture for Deployment Training Course*. This course has been prepared by the National ITS Architecture team and is informative about the

Architecture and how to use it, with practical interaction between students and the Architecture products on CD-ROM. Additional courses may become available.

National ITS Architecture Team

The National ITS Architecture documentation and the linked HTML model are available on the World Wide Web at <http://www.odetics.com/itsarch/>

Exploring The National ITS Architecture On Your Own:

- Read the Executive Summary first. Then read the Implementation Strategy—start with Chapter 4.
- Use the CD-ROM in concert with a "File Find" utility. Some "File Find" utilities will search the written material in a document for specific words. This will allow you to search the entire National ITS Architecture for specific information.
- Use the Market Packages as guides to the rest of the material in the National ITS Architecture or use them as a starting point. You can think of them as high-level ITS system designs that can be implemented as a project or sub-project.
- Read Sections 2.4 and 2.5 of the Implementation Strategy document for more details on how to explore the material.

ITS America

World Wide Web at
<http://www.itsa.org/public/archdocs/national.html>

Hard copy versions of the National ITS Architecture documentation may also be purchased from the ITS America Bookstore. Specific National ITS Architecture volumes are available.

Phone: (202) 484-4584 or 1-800-374-8472

The National ITS Architecture is also available on CD-ROM and includes an easy to use browser and search facility.

5.3 How Can I Find Out More About ITS Standards?

How can I find out the status of ITS standards development? Again, first verbal contact should be with your FHWA Division or FTA Region Office.

Detailed information on ITS Standards is available at the locations listed below:

National Transportation Communications ITS Protocol (NTCIP)

Contact the NTCIP Coordinator at the **National Electrical Manufacturers Organization (NEMA)**

Phone:	(703) 841-3231
Fax:	(703) 841-3331
World Wide Web at	<http://www.ntcip.org/standards>

Copies of papers regarding the NTCIP standards currently available from NEMA include:

- *National Transportation Communications For ITS Protocol (NTCIP) Guide (Draft)*, December 1, 1996.
- *Center-to-Center Communications Requirements and Issues (White Paper)*, December 16, 1996
- *NTCIP White Paper, Center-To-Center Communications*, November 27, 1996

Copies of NTCIP standards may be purchased from NEMA. Those NTCIP standards currently available include:

- NTCIP Overview (NEMA TS3.1) - This publication provides an overview of the concepts and protocols for the NTCIP series of standards, which can be used to implement a working NTCIP-based transportation control system. This standard encompasses roadside device control, data collection, data routing, and file transfer services using various communication system topologies.
- Simple Transportation Management Protocol (NEMA TS3.2) - The Simple Transportation Management Framework (STMF) describes the framework used for managing and communicating information between management stations and transportation devices. It covers integrated management of transportation networks, networking devices and transportation specific equipment attached to NTCIP-based networks.
- NTCIP Class B Profile (NEMA TS3.3) - This communications protocol standard can be used for interconnecting transportation and traffic control equipment over low bandwidth channels. This standard establishes a common method of interconnecting ITS field equipment such as traffic controllers and dynamic message signs (DMS), defines the protocol and procedures for establishing communications between those components, and references common data sets to be used by all such equipment.
- Global Object Definitions (NEMA TS3.4) - The messaging between transportation management and field devices is accomplished by using the NTCIP Application Layer services to convey requests to access or modify values stored in a given device; these parameters and their values are referred to as objects. The purpose of this standard is to identify and provide those object definitions that may be supported by multiple device types (e.g., actuated signal controllers and variable message signs).
- Actuated Controller Unit Object Definitions (NEMA TS3.5, ASC) - This standard defines objects which are specific to actuated signal controller units.

- Object Definitions for Dynamic Message Signs (NEMA TS3.6, DMS) - This standard contains object definitions to support the functionality of DMSs used for transportation applications.

There are a total of sixteen of the NTCIP standards, ten more than listed above. For more information about NTCIP standards, please refer to Appendix A.

Transit Communications Interface Profiles (TCIP)
Further information can be obtained from the following source:

World Wide Web at <http://www.tcip.org>

ITS America
Contact ITS America for listing of all ITS standards and status information on standards development.

ITS America, 400 Virginia Avenue SW, Suite 800, Washington, DC 20024

Phone: (202) 484-4847

World Wide Web at <http://www.itsa.org/notice.html>

Other Standards

The American Association of State Highway and Transportation Officials (AASHTO)
444 North Capitol Street, Suite 249, Washington, DC 20001
Focus: State-level Agency Participation and Roadside Infrastructure.

World Wide Web at <http://www.aashto.org/main/>

The American Society for Testing & Materials (ASTM)
Focus: Dedicated Short Range Communications (DSRC) systems.

World Wide Web at <www.astm.org>

The Institute of Electrical and Electronics Engineers (IEEE)
Focus: Electronics and Communications Message Sets.

World Wide Web at
<http://stdsbbs.ieee.org/groups/sec32/index.html>.

The Institute of Transportation Engineers (ITE)
525 School St. SW, Suite 410, Washington, DC 20024-2797

Focus: Traffic Management and Transportation Planning systems.

Phone: (202) 554-8050

World Wide Web at <http://www.ite.org/standards.htm>

The Society of Automotive Engineers (SAE)
Focus: In-vehicle and Traveler Information

World Wide Web at
<http://www.sae.org/prodserv/standard/stanOther
Standards

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References

See Section 5 for web page URLs, phone numbers and addresses for the primary sources for most of these documents. Also, please be aware that most Federal reports may be obtained through:

National Technical Information Service (NTIS), Technology Administration, U.S. Department of Commerce, Springfield, VA 22161

Phone: (703) 605-6000; Fax: (703) 321-8547.

World Wide Web at **http://www.fedworld.gov/ntis/ntishome.html**

An ETTM Primer for Transportation and Toll Officials, 1995, Institute of Transportation Engineers, Washington, DC

Assessment of ITS Benefits — Early Results, MP 95W0000192, 1995, Roberts, Donald L., and Dwight E. Shank. The MITRE Corporation, McLean, VA.

Building the ITI: Putting the National ITS Architecture into Action, 1997, Mitretek Systems, prepared for the U.S. Department of Transportation, Federal Highway Administration

CHART: Incident Response Evaluation Final Report, May 1996, COMSIS Corporation, prepared for the Maryland State Highway Administration.

Communications Handbook for Traffic Control Systems, April 1993, U.S. Department of Transportation, Federal Highway Administration, Washington D.C.

Courtesy Patrol Pilot Program, June 1993, Cuciti, P. and B. Janson, University of Colorado

Department of Transportation ś Intelligent Transportation Systems (ITS) Projects, January 1998, Washington, D.C.: U.S. Department of Transportation, Intelligent Transportation Systems Joint Program Office.

Deploying Integrated Intelligent Transportation Systems, This course describes integrated intelligent transportation system infrastructure deployment using the National ITS Architecture. The regional context is emphasized. Combines the technical and institutional components of integrated ITS infrastructure so that each is understood in context with regional decisions by state and local agencies. ITS Professional Capacity Building Course, Office of Traffic Management and Intelligent Transportation Systems (ITS) Applications, U.S. Department of Transportation, Federal Highway Administration,

World Wide Web at:... < http://www.fhwa.dot.gov/hst/pcb/itscord1.htm >

Developing Traffic Signal Control Systems Using the National ITS Architecture. This is an accompanying volume to this document intended for those involved in the planning, development, deployment and operation of ITS Traffic Signal Control Systems.

Developing Traveler Information Systems Using the National ITS Architecture. This is an accompanying volume to this document intended for those involved in the planning, development, deployment and operation of ITS Traveler Information Systems.

FHWA Federal-Aid ITS Procurement Regulations and Contracting Options, 1997, Booz-Allen & Hamilton, prepared for U.S. Department of Transportation, Federal Highway Administration

Final Report on Telecommunications Shared Resources: Legal and Institutional Issues, 1997, Apogee Research, prepared for U.S. Department of Transportation, Federal Highway Administration

Framework for Developing Incident Management Systems (Revised), October 1995, Koehne, J., F. L. Mannering, M. E. Hallenbeck, J. Nee, Prepared for Washington State Transportation Commission, WSDOT, FHWA.

Freeway Incident Management Handbook, FHWA-SA-91-056, To be available 1998/1999, Reiss, R. A. and W. M. Dunn, Jr., NTIS

Freeway Management Handbook, FHWA-SA-97-064, August 1997, James D. Carvell, Jr., Kevin Balke, Jerry Ullman, Katherine Fitzpatrick, Lewis Nowlin, Christopher Brehmer, Texas Transportation Institutute, FHWA

Freeway Service Patrols: A Nationwide Assessment, Report No. FHWA-SA-98-066, 1998, U.S. Department of Transportation, Federal Highway Administration

Guidelines for Funding Operations and Maintenance of ITS/ATMS,. January 1997. Ginger Daniels and Tim Starr, Texas Transportation Institute. Presented at the 76th Annual Meeting, Transportation Research Board, Washington D.C.

Incident Management: Challenges, Strategies, and Solutions for Advancing Safety and Roadway Efficiency, Final Technical Report, February 1997, ATA and Cambridge Systematics, Inc., prepared for the National Incident Management Coalition.

Incident Response Training – Refresher Course, 1996, Washington State Department of Transportation

Innovative Contracting Practices for ITS, April 1997, L. S. Gallegos & Associates, prepared for U.S. Department of Transportation, Federal Highway Administration

Innovative Contracting Procedures for ITS, 1996, Nossaman, Guthner, Knox & Elliott; Ernesto V. Fuentes & Associates; L.S. Gallegos & Associates; Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration.

Innovative Finance Strategies for Deploying ITS, This seminar provides a basic understanding of ITS project delivery strategies including alternative design-build and private sector construction and operation, basic understanding of alternative ITS financing strategies, including federal-aid funding, state and local funding, and innovative financing. ITS Professional Capacity Building Course, Office of Traffic Management and Intelligent Transportation Systems (ITS) Applications, U.S. Department of Transportation, Federal Highway Administration,

World Wide Web at <http://www.fhwa.dot.gov/hst/pcb/itscord1.htm>

Integrating ITS Within the Planning Process: An Interim Handbook, 1997, TransCore, prepared for U.S. Department of Transportation, Federal Highway Administration

Intelligent Transportation Infrastructure Benefits: Expected and Experienced, FHWA-JPO-96-008, 1996, MITRE Corporation, The. Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration. Available on the world wide web at http://www.its.dot.gov/docs /itibeedoc/fms.htm

Intelligent Transportation Systems Assessment of ITS Deployment, Review of Metropolitan Areas: Discussion of Crosscutting Issues, FHWA-JPO-96-0035, 1996, Blasio, Allan J., David W. Jackson, Anne C. Tallon, Anne C. McEwan, John P. O Donnell, Cambridge, Massachusetts: U.S. Department of Transportation, Volpe National Transportation Systems Center.

Intermodal Surface Transportation Efficiency Act of 1991, A Summary, FHWA-PL-92-008, 1992, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.

ITE Operations and Maintenance Conference — Summary of Findings, 1995, Kraft, Walter H., Institute of Transportation Engineers. Washington, D.C., PP-047.

ITE Recommended Practices for Operations and Management of ITS, 1998, Institute of Transportation Engineers, Washington, D.C.

ITS Benefits: Continuing Successes and Operational Test Results, 1997, Mitretek Systems, prepared for the U.S. Department of Transportation, Federal Highway Administration

ITS Deployment Guidance for Transit Systems: Technical Edition. This is an accompanying volume to this document intended for those involved in the planning, development, deployment and operation of transit management systems.

ITS Public/Private Partnerships Overview, This seminar describes various types of cooperative public/private partnerships, plus public/private partnership models for cost sharing, shared deployment, and franchising. It identifies institutional impediments, discusses risk sharing in ITS partnering, and presents successful case studies. ITS Professional Capacity Building Course, Office of Traffic Management and Intelligent Transportation Systems (ITS) Applications, U.S. Department of Transportation, Federal Highway Administration

World Wide Web at:.....<http://www.fhwa.dot.gov/hst/pcb/itscord1.htm>

ITS Software Acquisition Guidance, 1998, Mitretek Systems, prepared for U.S. Department of Transportation, Federal Highway Administration

Joint Operations In Operating and Maintaining Advanced Traffic Management Centers, 1996, Douglas W. Wersig, White Paper prepared for the National Conference on Operating and Maintaining Advanced Traffic Management Centers, Minneapolis, MN.

Key Findings From The Intelligent Transportation System (ITS) Program: What Have We Learned?, FHWA-JPO-96-0036, 1996, Mitretek Systems, Washington, D.C., U.S. Department of Transportation, Federal Highway Administration.

Motorist Assistance Patrol Benefit/Cost Evaluation, 1993, Mooney, S., M. Kirk, and E. Bruce, prepared for the Federal Highway Administration and the North Carolina Department of Transportation (Raleigh).

Overcoming Non-Technical Barriers: Lessons Learned From ITS Operational Tests, FHWA-JPO-96-0010, 1996, DeBlasio, Allan J,. Cambridge, Massachusetts: U.S. Department of Transportation, John A. Volpe National Transportation Systems Center.

Telecommunications Resource Guide, ITS JPO, U.S. Department of Transportation, Federal Highway Administration

- Tab A, ***Telecommunications in Transportation, A Summary of Key Issues***, FHWA-JPO-97-0019, February 1997

- Tab B, ***A Case For Telecommunications Analysis***, FHWA-JPO-97-0015, January 1997, Prepared by CSC and the Maryland Department of Transportation

The National Architecture for ITS: A Framework for Integrated Transportation into the 21st Century, 1997, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.

A Toolbox for Alleviating Congestion and Enhancing Mobility, Second Edition, 1989, Meyer, M., Institute of Transportation Engineers, Washington, D.C.

Traffic Control Systems Handbook, February 1996, FHWA-SA-95-032, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.

Traffic Operations, Traffic Signal Systems, and Freeway Operations, 1995, Institute of Transportation Engineers, Washington, D.C.

Using the National ITS Architecture for Deployment, This course, presented by the Architecture Team (Lockheed Martin and Odetics), gives the student the mechanics for implementing regional systems using the National ITS Architecture. U.S. Department of Transportation, ITS Joint Program Office

World Wide Web at:..... < http://www.fhwa.dot.gov/hst/pcb/itscord1.htm >

Virginia Department of Transportation Public-Private Procurement — Issues and Accomplishments, Interim Report for WMTIS, Undated, Booz Allen & Hamilton, prepared for U.S. Department of Transportation, Federal Highway Administration

When Seconds Count, Highway Travelers Can Count on the State of Connecticut, Connecticut Department of Transportation

Appendix A. ITS Standards

A.1 Overview

The intent of this appendix is to identify and describe existing and planned ITS standards that are applicable to traffic signal control systems. The need for these standards has been identified by transportation industry.

The development, promulgation, and adoption of standards is an issue of utmost importance in the use of a new technology. Adoption of standards can have a number of different effects. On one hand, the adoption of a technology in the marketplace can be stimulated. On the other hand, the further development of a technology could be frozen. Commercial broadcast television in the United States serves as an example of both of these effects.

> Early adoption of standards for commercial TV in the United States allowed for explosive growth of industry here in the immediate post-World War II years. However, U.S. technology was frozen at a level that subsequently proved to be inferior to that achieved soon after in Europe. The technology of communicating data over telephone lines provides a counter example. New standards for increasingly fast data transmission over the phone lines periodically emerge, but the new modems that capitalize on these standards also generally operate according to the old ones if such operation is needed. This capability for backward compatibility increases the flexibility for all users of a technology, thus spurring both greater adoption on the marketplace and further technological advancement.

Standards development is critical to the success of implementing ITS. Well defined standards help agencies better prepare procurement specifications, Requests For Information (RFIs), and Requests For Proposals (RFPs). These standards need to be open instead of proprietary in order to allow for new technologies and new products from different manufacturers to be added. Open standards are generally owned by a public organization, or the underlying technology is licensed on a low-cost, non-discriminatory basis by its owner, and made available to anyone wanting the documentation for an interface. Open standards encourage interoperability of products from different manufacturers. Proprietary standards have restricted access, usually to the company that developed the standard or their chosen licensees.

Utilizing standards to ensure ITS interoperability and the interchangeability of like equipment will benefit the transportation industry by decreasing procurement costs (larger numbers of competing manufacturers will spur competition), increasing system flexibility, and providing easy upgrade paths.

Even though equipment standards are important, this section does not provide equipment-specific standards because of the vast number of different equipment technologies. In addition, the establishment of strict standards for device-specifications is not only location-dependent but it would also restrict progress and innovation, and is therefore not desirable.

A.1.1 Previous work

Several organizations have been tasked, voluntarily and through contracts, to develop ITS-related standards. Existing standards are generally based on the need of a particular industry or agency. The U.S. DOT subsequently awarded a contract to the Jet Propulsion Laboratories (JPL) to serve as the lead organization to:

- Collect ITS-related standards
- Create a database
- Organize the standards in the database
- Maintain and update the database content
- Provide interested parties with the entire content or excerpts of it

The content of this database is updated continuously and it can be visited on the ITS America Internet home page at:

http://www.itsa.org/notice.html

under the heading "Standards Catalog."

A.2 Communication Standards

This overview of communication standards is designed to provide the reader with information on ITS-related communications protocols. The communication standards presented allow agencies to transmit data from one device or system to another. Some of these standards currently exist or are very close to being completed, while others are either in an early development or planning stage.

A.2.1 Overview

Since many interfaces have not been standardized, the U.S. DOT funded the development effort of creating standards for ITS technologies.

Some of these new standards for ITS are described below. The listing is neither complete nor does it indicate levels of importance.

A.2.1.1 NTCIP

The National Transportation Communications for ITS Protocol (NTCIP) was originally conceived to be an extension of the NEMA TS-2 Controller Standard covering traffic controller communications. The NEMA traffic control equipment manufacturers recognized that for true hardware interchangeability, the standard had to cover the more complex issues of systems interoperability and communications standards. As the NEMA development work grew, a general industry forum evolved and ultimately the Federal Highway Administration (FHWA) identified the concerns of ITS designers.

Today, the Joint NTCIP Committee, a steering committee consisting of members from three Standard Development Organizations (SDOs), NEMA, ITE, and AASHTO, is overseeing and directing all efforts with respect to NTCIP that are being executed within each of the above SDOs.

For ITS to be a reality, all the components that make up the traffic and transportation monitoring and control community must be able to communicate with a common, or at least understandable, language. The words that are spoken must have a clear and unambiguous meaning to everyone. The NTCIP development participants started out by defining a language needed for a traffic controller, and extended it to include Traffic Management Centers (TMCs). It has been further refined into an open set of protocols that meet the diverse needs of ITS.

This openness is achieved by embracing features of several existing worldwide communications standards established by the International Standards Organization (ISO), the International Telecommunications Union, Telecommunications Sector (ITU-T; formerly CCITT), and the Internet Engineering Task Force (IETF). These standards map onto the ISO Open Systems Interconnect Reference Model (OSI Model) that deals with how information can be passed through the various processing layers in an open system. The OSI Model breaks down the aspects of communications into seven layers or discrete functions to reduce complexity. Each layer is built upon its predecessor. These seven layers are shown in Figure A1.

Layer 7	Application Layer
Layer 6	Presentation Layer
Layer 5	Session Layer
Layer 4	Transport Layer
Layer 3	Network Layer
Layer 2	Data Link Layer
Layer 1	Physical Layer

Figure A1. OSI Layers

These seven layers can be viewed as forming two groups of functionality to support open communications. The first group (Layers 1-4) is responsible for data transport while the second group (Layers 5-7) is responsible for data processing.

Protocols utilized on the different layers of the OSI models are mostly existing computer standards that have been used for years within the industry. However, due to the nature of transportation infrastructures, a few new protocols and modifications to existing protocols had to be defined such as the development of the Simple Transportation Management Protocol (STMP), a new application layer protocol, and Point-to-MultiPoint Protocol (PMPP), which follows the existing Point-to-Point Protocol (PPP). PMPP has not yet been approved.

A.2.1.1.1 Class Profiles

Within the NTCIP there are various profile classes defined:

- A - Connectionless
- B - Central direct to field
- C - Connection oriented
- D - Dial-up
- E - Center to Center
- F - Alternate Center-to-Center

These classes are described below. The Class B Profile is the only Class Profile that has been standardized to date.

A.2.1.1.2 Class A Profile

Class A is a suite of protocols allowing the connectionless transmission of data packets over a medium that does not require a permanent connection between two devices. For example, when sending two letters via regular mail, it cannot be ensured that both letters will take the same route (one letter might get from location A to location B via location C, while the other letter is sent via location D). The Class A Profile is based on existing protocols already in use by the Internet community and other network systems, therefore utilizing proven protocols. The only exception is the utilization of STMP as the application layer protocol and a modified form of the HDLC protocol that includes an initial protocol identifier (IPI) as the data link layer protocol.

The Class A Profile suite of protocols will use the Transmission Control Protocol (TCP) as its Transport Layer protocol to guarantee delivery or signal when a message cannot be delivered correctly. TCP uses sequence and acknowledge information and timers to make sure the individual frames are received and that they are put in their proper order. If a frame is garbled or lost, re-transmissions are attempted. If a frame cannot be delivered, the upper layer is notified. This class of service ensures data integrity and correctness; its primary use is for large data transfers.

This standard has not yet been approved but is in the process of being developed by device manufacturers in conjunction with users of these devices. This development process ensures that the devices utilizing this protocol will meet the requirements of the user community.

The main difference between the Class A Profile and the Class B Profile is that Class A messages can be routed through an intermediate device, e.g., from a central location to a field device.

A.2.1.1.3 Class B Profile

The NTCIP Class B Profile defines a set of communication protocols to be used in field devices and their management systems that are part of an Intelligent Transportation System. The profile provides for exchange of information between a primary station and each secondary station on a particular communications channel or subnet. The profile sets forth standards to allow devices to share a common interconnect, establish a common language for them to communicate and define the structure under which the data in these devices is structured and managed. It does not address the need for the

exchange of information between devices on different subnets.

Class B provides for bandwidth efficient exchange of information between the primary station and each secondary station on the same physical link. Class B does not ensure delivery. Frames received with errors are discarded. If re-transmissions are needed, it is the responsibility of the Application Layer to provide them. This class of service is primarily intended for short command and reply messages where delivery time is a strong consideration.

The Class B Profile can be used to poll or transmit data to and from roadside devices such as traffic signal controllers, surveillance detectors, variable message signs, or preemption devices. It can also be used for communicating with traveler information kiosks or similar devices. A prerequisite is the direct connection of management center and roadside device, because the Class B Profile does not allow for routing of messages

A.2.1.1.4 Class C Profile

Class C is a profile providing connection-oriented services similar to the data transmission within the Internet. In fact, the Class C Profile includes the same protocols on the Network (using Internet Protocol or IP) and Transport (using TCP) Layers of the OSI model. This profile is not yet finalized but will probably not include the untested Simple Transportation Management Protocol (STMP), as required for the Class B and Class A Profiles. Instead, it will utilize the Simple Network Management Protocol (SNMP), TELNET, and the File Transfer Protocol (FTP), which are well-tested and implemented within the Internet and intranet networks.

Class C may seem to provide the ideal service; however, it imposes additional overhead. Before any information can be passed, a connection between the devices must be established. The connection procedure takes a certain amount of time. When the information transfer is completed, the connection must be formally closed.

The main difference between the Class C Profile and the Class B Profile is that Class C messages can be routed through an intermediate device, e.g., from a central location to a field device. Another aspect is the capability to 'chop "large data files into smaller data packets (file transfer) and to sequence these packets so that they can be assembled correctly at the receiving end.

A variety of traffic signal applications can benefit from the Class A and/or Class C Profiles. Different types of field devices, such as traffic signal controller, video surveillance cameras, and variable message signs, from various different manufacturers could be connected to one common communications line and still be controlled and monitored from the traffic management center. Currently, it is not possible to connect existing field devices that utilize different communications protocols to the same communications channel as NTCIP.

A.2.1.1.5 Class D Profile

The Class D Profile is intended for dial-up connections. The protocol will include security features such as dial-back. Development work on the Class D profile has not occurred yet.

A.2.1.1.6 Class E Profile

The Class E Profile specifies the suite of protocols that allows for center-to-center communications. The specification of this Profile is at a very preliminary stage and its anticipated development completion date is 1999. One of the first steps in developing this standard is the definition of the Transportation Management Data Dictionary (TMDD) specifying the content of data that needs to be transmitted between management centers.

Several different existing and emerging protocols, mostly specifying the application layer protocol and ultimately influencing the underlying layers of the OSI model, are under consideration for this profile but a consensus has not been reached.

The transportation industry can utilize this standard to ensure compatibility between multiple transportation management centers or service providers. The Class E Profile should not be used separately unless the data format of messages to be exchanged are known to both the transmitting and receiving management centers.

A.2.1.1.7 Class F Profile

Another NTCIP compatible and NTCIP-compliant method for center-to-center communications has been introduced. The introduction of a Class F Profile took place in December 1996 but the information regarding this proposed standard development effort has not yet been specified in writing.

A.2.1.1.8 Message Sets

NTCIP utilizes message sets that define how a particular function or parameter is defined and described, and what the allowed ranges are for each parameter (or objects as they are called). All objects have a unique name which is based on a location under a global tree. NEMA has a node (or branch) within the global tree and assigns unique names to each known and defined object. Because of the history, NEMA first tried to define signal controller objects, but detected very quickly that many objects (parameters and/or functions) are not unique to signal controller applications (e.g., time) and created another message set that contains common objects (referred to as Global Object Definitions). These message sets were finalized in Winter 1996/97 and are available from NEMA (see Section 5)

A.2.1.1.9 Future Developments

NTCIP is envisioned to cover many different types of communications. The flexibility of NTCIP achieved through following the OSI Reference Model allows the expansion to various, not yet considered communications protocols on the different layers of the OSI model. Interoperability is provided by defined interface setups (APIs) that the layer protocols are required to follow.

A.2.1.2 TCIP

The Transit Communications Interface Profiles (TCIP) is a standards development effort that may consist of several suites of protocols and data message sets. TCIP's primary goal is the definition of data interfaces to both transit-related applications and the National ITS Architecture data flows. Transit-related application interfaces are anticipated to include the FTA National Transit GIS standard (under development, see below) and consider the Advanced Public Transit Systems (APTS) Map and Spatial Database User Requirement specifications (also under development) as well as the NTCIP, DSRC, and other standardization efforts. TCIP will be developed by addressing data flows as identified within the National ITS Architecture to the greatest extent possible. Interfaces needed for other transit-related applications that have not been addressed will also be identified.

The TCIP development effort is expected to augment the information management area of NTCIP with transit-related information and message formats that facilitate the exchange of transit information among operations centers, transit vehicles and the infrastructure. The TCIP will provide additional NTCIP Class Profiles or subsets of existing and planned Class Profiles, and the necessary bridges for information transfer from legacy transit systems to advanced information systems developed conforming to the National ITS Architecture. The characteristics of transit information exchange may be best served, for example, by one of the five NTCIP Class Profiles, by one of the Profiles of SAE J1708, or by TCIP. However, the main focus of TCIP will be the development of message formats to exchange transit information in a standardized manner.

The TCIP effort is lead by the Institute of Transportation Engineers (ITE) and supported by a large group of technical advisors consisting of members of the transit community such as FTA, APTS, and APTA. ITE is a recognized Standard Development Organization (SDO) that was awarded a contract by the US DOT to develop the TCIP standard. The time frame for the TCIP development ends in June 1998.

The following have been identified as preliminary targets for the TCIP work:

1.) data flows internally and externally:

a.) internal data flows:	interdepartmental within a transit property or within the different branches (remote offices), Transit Management Center (TrMC) to transit vehicles, transit kiosks, and other items such as roadside transmitters
b.) external data flows:	TrMC to TMC or other centers such as service providers and financial agents (e.g., credit card companies and banks)

2.) static reference and dynamic data transfers:

a.) static reference data flows:	for example, route and bus stop inventory, schedule, fare, and spatial data transfers
b.) dynamic data flows:	for example, pre-trip itinerary planning, safety and security information, and detour and

service delay data transfers TCIP will ensure interoperability and compatibility to NTCIP and SAE J1708/J1587 by creating gateway protocols, also termed application programming interfaces (APIs).

Further information can be obtained from the following source:

http://www.tcip.org

A.2.1.3 Dedicated Short Range Communications (DSRC)

Dedicated Short Range Communications (DSRC) consists of short-range communications devices that are capable of transferring high rates of data over an air interface between mobile or stationary vehicles and normally stationary devices that are either mounted to structures along the roadway or are hand-held. One way of accomplishing these communications is through use of radio frequency (RF) beacons. RF beacon technology generally consists of a transponder (tag), transceiver (reader), and transceiver antenna (beacon). DSRC is also known as vehicle-roadside communications (VRC).

The National ITS Architecture program recognizes the need for DSRC systems for those specific applications that require a close physical interaction between the vehicle and the roadside infrastructure, such as in toll collection, commercial vehicle electronic clearance and roadside safety inspection, etc. However, DSRC is considered inappropriate for applications such as route guidance that can be more efficiently served by wide-area ITS communications. Because of the dedicated nature and limited range of DSRC systems, the National ITS Architecture realizes that the costs of deploying DSRC will have to be absorbed by the ITS applications they support, including both public and private investment. The technical and applications aspects of DSRC are covered in the Communications, Physical Architecture and Theory of Operations documents produced by the National ITS Architecture program.

The following applications have been identified as candidates to utilize DSRC as a primary communications technique or mechanism:

Ë Electronic Toll and Parking Payments

Ë Commercial Vehicle Operations

  $ International Border Clearance

  $ Electronic Clearance

  $ Safety Inspection

  $ Automated Equipment Identification and Freight Management

  $ Off-Line Verification

Ë Transit and Emergency Vehicle Operations

Ë Fleet Management

Ë Use of Vehicles as Probes to Obtain Link Travel Times

Ë In-Vehicle Signing

Ë Intersection Collision Avoidance and Automated Highway Systems

Ë Commercial Applications (e.g., drive-through purchases)

Ë Intersection Safety Warning

To support deployment of nationally, and perhaps internationally, compatible Intelligent Transportation Systems using DSRC, the ITS Joint Program Office (JPO) in the U.S. Department of Transportation issued a work order to build consensus and generate the necessary documentation to support the process for developing a dedicated short range communications standard for ITS applications, both for the near term and for the long term. PB Farradyne Inc. has been selected for this work order that will produce a concept of operations, a Migration Plan, and a Global Harmonization document to serve as the foundation for the standard setting efforts. Separate work orders were issued to begin establishing standards using the OSI Reference Model as a basis. Leading this effort are the American Society for Testing and Materials (ASTM) and Institute of Electrical and Electronic Engineers (IEEE).

A report has been prepared that functions as a Concept of Operations. It describes consensus among the user and vendor communities as to the operation of all ITS applications that require use of DSRC. This is largely based on the state of the practice, and activities underway to support integration of different applications and technologies, so that a single tag could be used for multiple applications, or tags from multiple vendors could be used for the same application.

A.3 Automated Vehicle Location (AVL) Systems

The application of AVL is a very beneficial application in terms of implementing ITS technologies. It will enable fleet, transit and emergency services managers to manage vehicles in real-time with reference to the roadway network.

There are many AVL systems in existence. However, all of these AVL systems are proprietary, locking implementing agencies into a vendor-specific system. Most of these AVL systems have not been designed to allow for integration with an overall management system. Therefore, expansion to include upgrades, include other subsystems, or the integration of an AVL system into an overall management system will be very expensive.

The transportation industry has expressed the need for an AVL standard to allow for interoperability and integration of subsystems. The U.S. DOT placed AVL high on the priority list of standards that need to be developed for ITS technologies.

The Institute of Electrical and Electronic Engineers (IEEE) has been designated as the lead organization to develop the message set (applications standard) for AVL. However, other standards specifying the communications protocols are also needed.

Currently existing and planned standards usable for AVL are listed in the ITS Standards Catalog available on-line at the following website:

http:\\www.itsa.org

Appendix B. Glossary

Advanced Traffic Management Systems (ATMS) - The Advanced Traffic Management System category of ITS functions. Includes adaptive traffic signal control, electronic road pricing, and toll collection.

Advanced Traveler Information Systems (ATIS) - The Advanced Traveler Information System category of ITS functions. Includes vehicle navigation, route guidance, in-vehicle signage, intermodal travel information, trip planning, and mayday communication.

Algorithm - A procedure, process, or rule for the solution of a problem in a finite number of steps. An algorithm may be a set of computational rules for the solution of a mathematical problem or for evaluating a function.

Advanced Public Transportation Systems (APTS) - The Advanced Public Transportation System category of the ITS functions. Includes vehicle location and schedule monitoring, real-time transit, ride-share and HOV information.

Architecture Flow - A grouping of data flows (from the logical architecture) that originate at one subsystem and end at another (in the physical architecture).

Automated Vehicle Identification (AVI) - System that has three functional elements: a vehicle-mounted transponder (also known as a vehicle tag); roadside reader unit (also known as a tag reader); and a processing control unit.

Automated Vehicle Location (AVL) - A computerized system that tracks the current location of vehicles, buses, etc., enabling fleets to function more efficiently.

CCTV - Closed Circuit Television

CCTV Monitoring Systems - Advanced traffic management systems with continuous CCTV coverage of the transportation facilities (e.g. freeways, intersections, bridges).

Command - A signal (typically from the central computer or master controller) that initiates a control function.

Communication System - The composite of communication links and associated communications equipment which interconnect all the control and surveillance components of a traffic control system.

Communications Addressing - The process of selecting a specific receiving unit on a multidrop line or network so that the message can be sent to the unit alone.

Communications Control Unit (CCU) - The portion of a system that handles the communication processes. The CCU may be a software program or a separate hardware unit. It handles message transmission, errors, control functions, and other communication-related tasks.

Congestion - A freeway condition where traffic demand exceeds roadway capacity. Normally occurs during peak travel periods or when a traffic incident reduces capacity by creating a bottleneck.

Congestion Strategy - A strategy that optimizes corridor operations to minimize the spread of congestion.

Council of ITS Standards - The council established by ITS America (Standards and Protocol Committee) to coordinate the standards-setting efforts in USA and international. Includes representatives from ANSI, IEEE, SAE, ASTM, EIA, NAB, NEMA, TIA, ITE, and AASHTO.

Delay - The retardation of traffic flow through a segment of roadway or intersection for a definite period of time.

Demand - The need for service, e.g., the number of vehicles desiring use of a given segment of roadway or intersection during a specified unit of time.

Detector - A device for indicating the presence or passage of vehicle or pedestrians. The general term is usually supplemented with a modifier; loop detector, magnetic detectors, etc. indicating type.

Diversion - An aspect of corridor control which refers to the directing of traffic from a corridor with excess demand to those with excess capacity.

Diversion Strategy - a strategy for diverting traffic that optimizes corridor operations in response to corridor incidents.

Emergency Management - The bundle of ITS user services that includes; emergency notification and personal security; and emergency vehicle management.

Equipment Status Monitoring - The ability to determine the operational characteristics of a remote device in terms of: *operating normally, malfunctions, communications errors*, etc.

Hardware - The physical equipment in a computer system. (see *Software*).

Highway Advisory Radio (HAR) - Also know as Traveler s' Information Stations (TIS), or Traveler s' Advisory Radio (TAR). These systems provide travel or roadway information to motorists via their AM radio sets. The FCC regulates the use of HAR.

Incident - An occurrence in the traffic stream which causes a reduction in capacity or abnormal increase in demand. Common incidents include accidents, stalled vehicles, spilled loads, and special events.

Intelligent Transportation Systems (ITS) - The collection of transportation services and infrastructure that will implement the goals of ISTEA. ITS uses advanced technologies to provide the range of traffic-based user services.

Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA-91) - A Congressional act whose purpose is to develop a National Intermodal Transportation System that is economical efficient and environmentally sound, provide the foundation to compete in the global economy and move people and goods in an energy efficient manner. Provides governmental basis for research and deployment of ITS technologies.

International Organization for Standardization (ISO) - An international standards organization. ANSI is the U.S. representative to ISO.

Intersection - The common area of roadways that meet or cross.

Layer - A breakdown or stratification of the physical architecture; comprised of the transportation layer and the communications layer.

Logical Architecture - The identification of system functional processes and information flows grouped to form particular transportation management functions. These processes are broken down into subprocesses and further into process specifications or p-specs.

Mainline: Freeway - The freeway proper as distinguished from the entrance ramps, exit ramps, and interchange geometry of the freeway.

Measures of Effectiveness (MOE) - The quantitative variables derived from traffic measurements that measure the improvement in traffic operations ranging from one signalized intersection to a complete system. Common MOEs are total travel time, total travel, number and recent of stops, delay, average speed, accident rate, and throughput.

Metering - Traffic control method or technique for regulating traffic flow.

Metering Rate - Number of vehicles allowed to enter a given section of roadway per unit time.

National Transportation Communications for ITS Protocol (NTCIP) - A family of protocols being developed for the transportation community.

NEMA - National Electrical Manufacturers Association, a standards development body.

Occupancy - Percent of time that a point on a roadway is occupied by a vehicle.

Open Systems Interconnect Reference Model (OSI Model) - A communications model established by the International Standards Organization (ISO) that breaks down the aspects of communications into seven layers or discrete functions to reduce complexity and provide support for open communications. The layers range from the physical layer to the application layer.

Physical Architecture - The physical (versus functional) view or representation of a system.

Process Specifications - The lowest level of functional hierarchy, process specifications (also know as p-specs) are elemental functions that must be performed to satisfy user service requirements.

Project Management - A management process that transforms a design into an installed system. Uses management tools such as: contract administration; project scheduling; construction management; work breakdown structure; defined and budgeted work packages; project design reviews and audits; and costs/progress status reports. This process carries forward the implementation of the system design. Tasks include: procurement of subsystems, software, and equipment, contractor performance monitoring, documentation; design reviews, development, integration, development testing, acceptance testing; training, hands-on training, and turnover to user, followed by a warranty period covering design, construction, installation and operational

Queue Detector - (1) A vehicle presence detector installed on a freeway entrance ramp just downstream of the frontage road to detect queue spillback onto the frontage road. (2) Component of a traffic signal control system which senses the presence (or number) of vehicles waiting in a queue.

Queue Length - (1) Number of vehicles stopped in a lane behind the stopline at a traffic signal. (2) Number of vehicles that are stopped or moving in a line where the movement of each vehicle is constrained by that of the lead vehicle.

Ramp Metering - The most widely used form of freeway traffic control. It regulates the number of vehicles entering the freeway over a given time interval so that demand does not exceed capacity.

Ramp Metering Signal - Traffic signal which directs entrance ramp vehicles to stop and permits them to proceed in accordance with metering rates determined by the type of entrance ramp control being used.

Real-Time, Traffic-Responsive Control System - Traffic control system which evaluates and selects control actions continuously on the basis of current measures of traffic conditions.

Recurrent Congestion - A type of congestion which is routinely expected at predictable locations during specific time periods

Software - Various computer programs to facilitate the efficient operation of the system. Software items include: assemblers; compilers, generators; subroutines; libraries; operating systems; and application programs.

Software Maintenance - Those tasks required to locate and correct errors remaining in computer programs after they are placed in operation, as well as making other program modifications to meet the demands of changing system needs. This is an ongoing activity that is required on any large automated system.

Subsystem - A physical entity within the transportation layer of the National ITS Architecture.

Threshold - A present level or value of a parameter which indicates that a change of activity will occur if the current value is above or below this level.

Traffic Flow Rate - Number of vehicles passing a point on the roadway during a specified time period.

Transit Communications Interface Profiles (TCIP) - A subset of NTCIP protocols which are specific to the transit community.

Urban Traffic Control System (UTCS) - A widely deployed real-time traffic responsive system control system originally developed by the Federal Highway Administration (FHWA) and prototyped in Washington, D.C.

User Service Bundles - A collection of ITS user services that have common characteristics and can be deployed in a coordinated manner.

User Service Requirement - The decomposition of each user service into fundamental needs.

Variable Message Sign (VMS) - Signs that electronically or mechanically vary the visual word, number or symbolic display as traffic conditions warrant. Also referred to as changeable message signs or as dynamic message signs.

Wide Area Network - Any one of a number of technologies that provides geographically distant transfer.

Appendix C. Physical Architecture Data Flows

The physical architecture allocates the functionality defined in the logical architecture into subsystems based on the functional similarity of the process specifications and the typical locations of functions in transportation systems. By defining four subsystem classes (Traveler, Roadway, Center and Vehicle) and 19 subsystems, the National ITS Architecture provides a framework for development of a regional physical architecture. Once the subsystems of the physical architecture have been defined, and the interfaces required between them identified, a detailed system design can be developed.

C.1 Data Flows Associated with Freeway Management

Figure C-1 provides an illustration of the physical data flows into and out of the Traffic Management Subsystem.

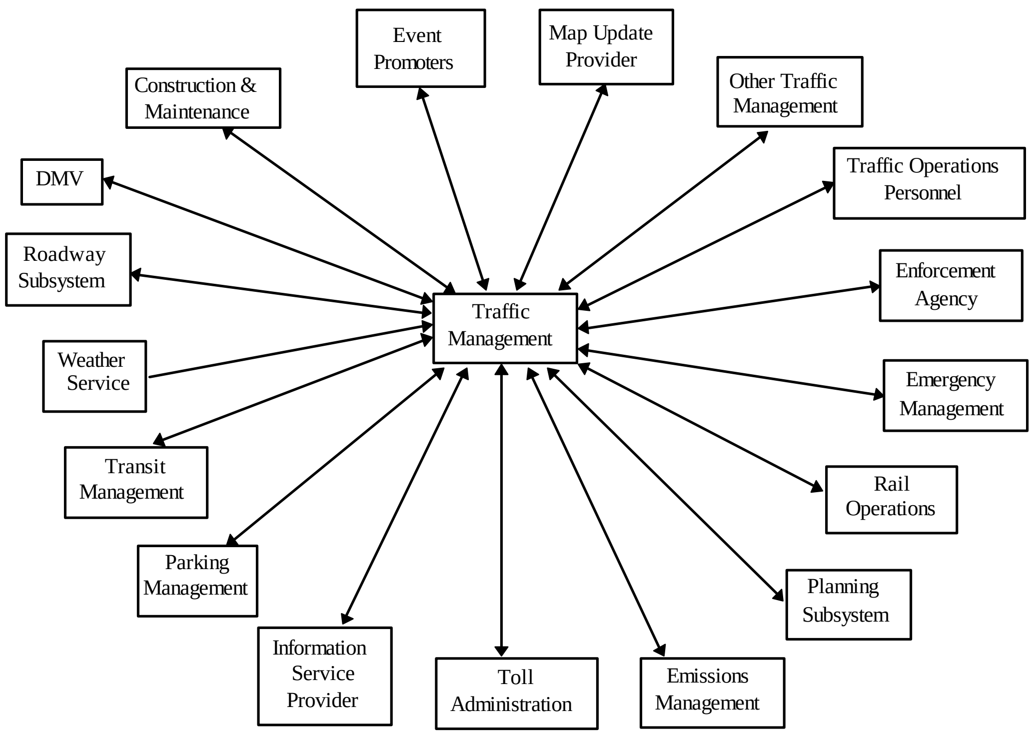

Figure C-1. Physical Data Flows for Traffic Management

The balance of Appendix C lists important physical data flows that may be associated with freeway management or incident management systems.[1] The format of each is as follows:

- Heading (bold) - Source subsystem to destination subsystem
- Physical Architecture flow name - italics
- Brief description of the data flow - line following Physical Architecture flow name
- Logical Architecture Reference Flow (bullets) - Logical data flows which comprise the Physical Architecture data flow

This list does not constitute the entire list of data flows that may be relevant to freeway or incident systems. For example, data flows exchanged with most external system interfaces (or terminators) are not included. Guidance for locating complete data flow lists for each market package is provided in Section 2.

Construction and Maintenance -> Traffic Management

Physical Architecture Flow Name: *work zone status*

status of maintenance zone

- Logical Architecture Reference Flow: fcm_incident_information
- Logical Architecture Reference Flow: fcm_fault_clearance

DMV -> Traffic Management

Physical Architecture Flow Name: *registration*

registered owner of vehicle and owner information

- Logical Architecture Reference Flow: fdmv_traffic_violation_vehicle_registration
- Logical Architecture Reference Flow: fdmv_traffic_violation_state_identity

Emergency Management -> Traffic Management

Physical Architecture Flow Name: *emergency vehicle greenwave request*

request for greenwave for emergency vehicle

- Logical Architecture Reference Flow: emergency_vehicle_green_wave

[1] *This appendix was derived from the January 1997 version of the National ITS Architecture. Since this information is subject to change as updates are implemented, the reader should always consult and defer to the latest version of the National ITS Architecture (see Section 5 of this document).*

Physical Architecture Flow Name: *incident information*

notification of existence of incident and expected severity, location, and nature of incident.

- Ë Logical Architecture Reference Flow: incident_details

Physical Architecture Flow Name: *incident response status*

status of currently occurring incident

- Ë Logical Architecture Reference Flow: incident_response_status

Emergency Vehicle Subsystem -> Roadway Subsystem

Physical Architecture Flow Name: *emergency vehicle preemption request*

request to TMS for signal preemption either through roadside or directly to TMS

- Ë Logical Architecture Reference Flow: emergency_vehicle_preemptions

Emissions Management -> Traffic Management

Physical Architecture Flow Name: *wide area statistical pollution information*

emissions from vehicles as measured at the roadside

- Ë Logical Architecture Reference Flow: pollution_state_data
- Ë Logical Architecture Reference Flow: pollution_incident
- Ë Logical Architecture Reference Flow: wide_area_pollution_data

Event Promoters -> Traffic Management

Physical Architecture Flow Name: *event plans*

plans for major events impacting traffic

- Ë Logical Architecture Reference Flow: fep_event_information

Information Service Provider -> Traffic Management

Physical Architecture Flow Name: *incident notification*

notification by a motorist of an incident on the roadway through the emergency network

- Ë Logical Architecture Reference Flow: media_incident_data_updates
- Ë Logical Architecture Reference Flow: confirm_incident_data_output

Physical Architecture Flow Name: *logged route plan*

route plan that may be used for demand management or optimal routing

- Ë Logical Architecture Reference Flow: logged_hazmat_route
- Ë Logical Architecture Reference Flow: low_traffic_route

Physical Architecture Flow Name: *request for traffic information*

request issued to agency which collects traffic data for traffic conditions

- Ë Logical Architecture Reference Flow: request_incident_media_data
- Ë Logical Architecture Reference Flow: traffic_data_media_request

Physical Architecture Flow Name: *road network use*

aggregated OD data from clients for planning purposes

- Ë Logical Architecture Reference Flow: parking_lot_charge_details
- Ë Logical Architecture Reference Flow: current_other_routes_use
- Ë Logical Architecture Reference Flow: current_transit_routes_use
- Ë Logical Architecture Reference Flow: current_road_network_use

Map Update Provider -> Traffic Management

Physical Architecture Flow Name: *map updates*

either static or real-time map updates

- Ë Logical Architecture Reference Flow: fmup_traffic_display_update
- Ë Logical Architecture Reference Flow: fmup_demand_display_update
- Ë Logical Architecture Reference Flow: fmup_incident_display_update

Other TM -> Traffic Management

Physical Architecture Flow Name: *TMC coordination* traffic information exchanged between TMCs. Normally could include congestion data, traffic data, signal timing plans, real-time signal control information.

- Ë Logical Architecture Reference Flow: fotc_data_request
- Ë Logical Architecture Reference Flow: fotc_identity
- Ë Logical Architecture Reference Flow: fotc_transfer_data
- Ë Logical Architecture Reference Flow: parking_lot_charge_change_response

Parking Management -> Traffic Management

Physical Architecture Flow Name: *demand management price change response*

response to change request indicating level of compliance with request

Physical Architecture Flow Name: parking availability

parking lot occupancy and availability

- Ë Logical Architecture Reference Flow: parking_lot_current_state
- Ë Logical Architecture Reference Flow: parking_guidance_for_vms

Planning Subsystem -> Traffic Management

Physical Architecture Flow Name: *planning data*

data to Transportation Planners

- Ë Logical Architecture Reference Flow: link_data
- Ë Logical Architecture Reference Flow: supply_incident_static_data
- Ë Logical Architecture Reference Flow: static_data_request
- Ë Logical Architecture Reference Flow: supply_traffic_static_data
- Ë Logical Architecture Reference Flow: traffic_data_deployment_request

Rail Operations -> Traffic Management

Physical Architecture Flow Name: *railroad advisories*

real-time notification of railway incidents

- Ë Logical Architecture Reference Flow: fro_incident_notification

Physical Architecture Flow Name: *railroad schedules*

train schedules, maintenance schedules, and other information from the railroad that supports forecast of HRI closures.

- Ë Logical Architecture Reference Flow: fro_maintenance_schedules
- Ë Logical Architecture Reference Flow: fro_train_schedules

Roadway Subsystem -> Traffic Management

Physical Architecture Flow Name: *fault reports*

reports from signals and displays on the roadside which are not functioning properly

Physical Architecture Flow Name: *HOV data*

HOV data from roadside indicating information regarding vehicle occupancy in HOV lanes

- Ë Logical Architecture Reference Flow: roadside_fault_data
- Ë Logical Architecture Reference Flow: hov_lane_data_input

Physical Architecture Flow Name: *hri status*

status of the highway-rail intersection equipment including both the current state or mode of operation and the current equipment condition

- Ë Logical Architecture Reference Flow: hri_guidance_for_beacon_message
- Ë Logical Architecture Reference Flow: hri_guidance_for_vms
- Ë Logical Architecture Reference Flow: hri_status
- Ë Logical Architecture Reference Flow: hri_traffic_data
- Ë Logical Architecture Reference Flow: rail_operations_message
- Ë Logical Architecture Reference Flow: traffic_management_request

Physical Architecture Flow Name: *incident data*

incident imagery and other data from roadside

- Ë Logical Architecture Reference Flow: incident_analysis_data
- Ë Logical Architecture Reference Flow: vehicle_pollution_alert
- Ë Logical Architecture Reference Flow: vehicle_pollution_message_for_highways

- Ë Logical Architecture Reference Flow: vehicle_pollution_message_for_roads

Physical Architecture Flow Name: *intersection blockage notification*

notification that a highway-rail intersection is obstructed and supporting information

- Ë Logical Architecture Reference Flow: hri_blockage
- Ë Logical Architecture Reference Flow: intersection_blocked

Physical Architecture Flow Name: *local traffic flow*

traffic flow over local streets

- Ë Logical Architecture Reference Flow: traffic_image_data
- Ë Logical Architecture Reference Flow: traffic_sensor_data

Physical Architecture Flow Name: *signal control status*

status of surface street signal controls

- Ë Logical Architecture Reference Flow: indicator_input_data_from_roads

Physical Architecture Flow Name: *signal priority request*

request for priority at signal either generated by emergency vehicle or transit vehicle. May be dealt with at roadside or forwarded to TMC

- Ë Logical Architecture Reference Flow: indicator_input_data_from_roads

Toll Administration -> Traffic Management

Physical Architecture Flow Name: *demand management price change response*

response to change request indicating level of compliance with request

- Ë Logical Architecture Reference Flow: toll_price_changes_response

Physical Architecture Flow Name: *probe data*

aggregate data from probe vehicles including location, speed for a given link or collection of links.

- Ë Logical Architecture Reference Flow: probe_data_for_traffic

Traffic Management -> Emergency Management

Physical Architecture Flow Name: *incident information request*

request for incident information, clearing time, severity

- Ë Logical Architecture Reference Flow: incident_details_request

Physical Architecture Flow Name: *incident notification*

notification of an incident on the roadway through emergency network

- Ë Logical Architecture Reference Flow: incident_alert
- Ë Logical Architecture Reference Flow: incident_response_clear

Traffic Management -> Information Service Provider

Physical Architecture Flow Name: *traffic information*

congestion, pricing, and incident information

- Ë Logical Architecture Reference Flow: current_highway_network_state
- Ë Logical Architecture Reference Flow: current_road_network_state
- Ë Logical Architecture Reference Flow: incident_data_output
- Ë Logical Architecture Reference Flow: link_data_for_guidance
- Ë Logical Architecture Reference Flow: parking_lot_charge_request
- Ë Logical Architecture Reference Flow: predicted_incidents
- Ë Logical Architecture Reference Flow: prediction_data
- Ë Logical Architecture Reference Flow: retrieved_incident_media_data
- Ë Logical Architecture Reference Flow: traffic_data_for_media
- Ë Logical Architecture Reference Flow: traffic_data_media_parameters
- Ë Logical Architecture Reference Flow: transit_fare_request

Traffic Management -> Other TM

Physical Architecture Flow Name: *TMC coordination*

traffic information exchanged between TMCs. Normally could include congestion data, traffic data, signal timing plans, real-time signal control information

- Ë Logical Architecture Reference Flow: totc_data_request
- Ë Logical Architecture Reference Flow: totc_identity
- Ë Logical Architecture Reference Flow: totc_transfer_data

Traffic Management -> Rail Operations

Physical Architecture Flow Name: hri advisories

notification of Highway-Rail Intersection equipment failure, intersection blockage, or other condition requiring attention, and maintenance activies at or near highway rail intersections

- Ë Logical Architecture Reference Flow: tro_event_schedules
- Ë Logical Architecture Reference Flow: tro_equipment_status
- Ë Logical Architecture Reference Flow: tro_incident_notification

Traffic Management -> Roadway Subsystem

Physical Architecture Flow Name: hri control data

HRI information transmitted at railroad grade crossings and within railroad operations

- Ë Logical Architecture Reference Flow: rail_operations_advisories
- Ë Logical Architecture Reference Flow: indicator_sign_control_data_for_hri
- Ë Logical Architecture Reference Flow: rail_operations_device_command

Physical Architecture Flow Name: hri request

a request for HRI status or a specific control request intended to modify HRI operation

- Ë Logical Architecture Reference Flow: hri_traffic_surveillance
- Ë Logical Architecture Reference Flow: ro_requests
- Ë Logical Architecture Reference Flow: tms_requests

Physical Architecture Flow Name: signage data

information sent to vehicles about traffic

- Ë Logical Architecture Reference Flow: vehicle_sign_data

Physical Architecture Flow Name: *signal control data*

Control information to surface street signals

- Ë Logical Architecture Reference Flow: indicator_control_data_for_roads
- Ë Logical Architecture Reference Flow: indicator_control_monitoring_data_for_roads

Physical Architecture Flow Name: *surveillance control*

control signals for surveillance devices

- Ë Logical Architecture Reference Flow: incident_video_image_control
- Ë Logical Architecture Reference Flow: traffic_video_camera_control

Traffic Management -> Operations Personnel

Physical Architecture Flow Name: *traffic operations data*

data detailing performance of the road network including current and historical data

- Ë Logical Architecture Reference Flow: ttop_video_image_output
- Ë Logical Architecture Reference Flow: ttop_traffic_control_information_display
- Ë Logical Architecture Reference Flow: ttop_current_indicator_faults
- Ë Logical Architecture Reference Flow: ttop_undefined_response_details
- Ë Logical Architecture Reference Flow: ttop_possible_incidents_data
- Ë Logical Architecture Reference Flow: ttop_incident_information_display
- Ë Logical Architecture Reference Flow: ttop_defined_incident_responses_data
- Ë Logical Architecture Reference Flow: ttop_possible_defined_response_output
- Ë Logical Architecture Reference Flow: ttop_incident_video_image_output

Traffic Management -> Transit Management

Physical Architecture Flow Name: *demand management price change request*

request to change the pricing for road facility use based on demand

- Ë Logical Architecture Reference Flow: transit_services_demand_request

- Ë Logical Architecture Reference Flow: transit_conditions_demand_request
- Ë Logical Architecture Reference Flow: transit_services_changes_request

Physical Architecture Flow Name: *signal priority status*

status of signal priority request functions at the roadside (e.g. enabled or disabled)

- Ë Logical Architecture Reference Flow: transit_highway_priority_given

Physical Architecture Flow Name: *traffic information*

congestion, pricing, and incident information

- Ë Logical Architecture Reference Flow: prediction_data

Traffic Operations Personnel -> Traffic Management

Physical Architecture Flow Name: *traffic control*

instructions to the TMC from an operator to adjust signal timing plans, change CMS or roadway signing, demand factors etc.

- Ë Logical Architecture Reference Flow: ftop_defined_incident_response_data_update
- Ë Logical Architecture Reference Flow: ftop_incident_camera_action_request
- Ë Logical Architecture Reference Flow: ftop_incident_data_amendment
- Ë Logical Architecture Reference Flow: ftop_defined_incident_response_data_request
- Ë Logical Architecture Reference Flow: ftop_update_defined_incident_responses
- Ë Logical Architecture Reference Flow: ftop_traffic_information_requests
- Ë Logical Architecture Reference Flow: ftop_incident_information_requests
- Ë Logical Architecture Reference Flow: ftop_video_camera_action_request
- Ë Logical Architecture Reference Flow: ftop_traffic_data_parameter_updates

Transit Management -> Traffic Management

Physical Architecture Flow Name: *request for transit signal priority*

request for signal priority either through roadside or directly to TMS

- Ë Logical Architecture Reference Flow: transit_highway_overall_priority

Transit Vehicle Subsystem **->** **Roadway Subsystem**

Physical Architecture Flow Name: *local signal priority request*

request between vehicle and roadside

- Logical Architecture Reference Flow: transit_vehicle_roadway_priority_request

Weather Service **->** **Traffic Management**

Physical Architecture Flow Name: *weather information*

predicted and accumulated weather data

- Logical Architecture Reference Flow: from_weather_service
- Logical Architecture Reference Flow: fws_current_weather
- Logical Architecture Reference Flow: fws_predicted_weather

C.2. Data Flows Associated With Incident Management

Figure C-2 provides an illustration of the physical data flows into and out of the Emergency Management Subsystem.

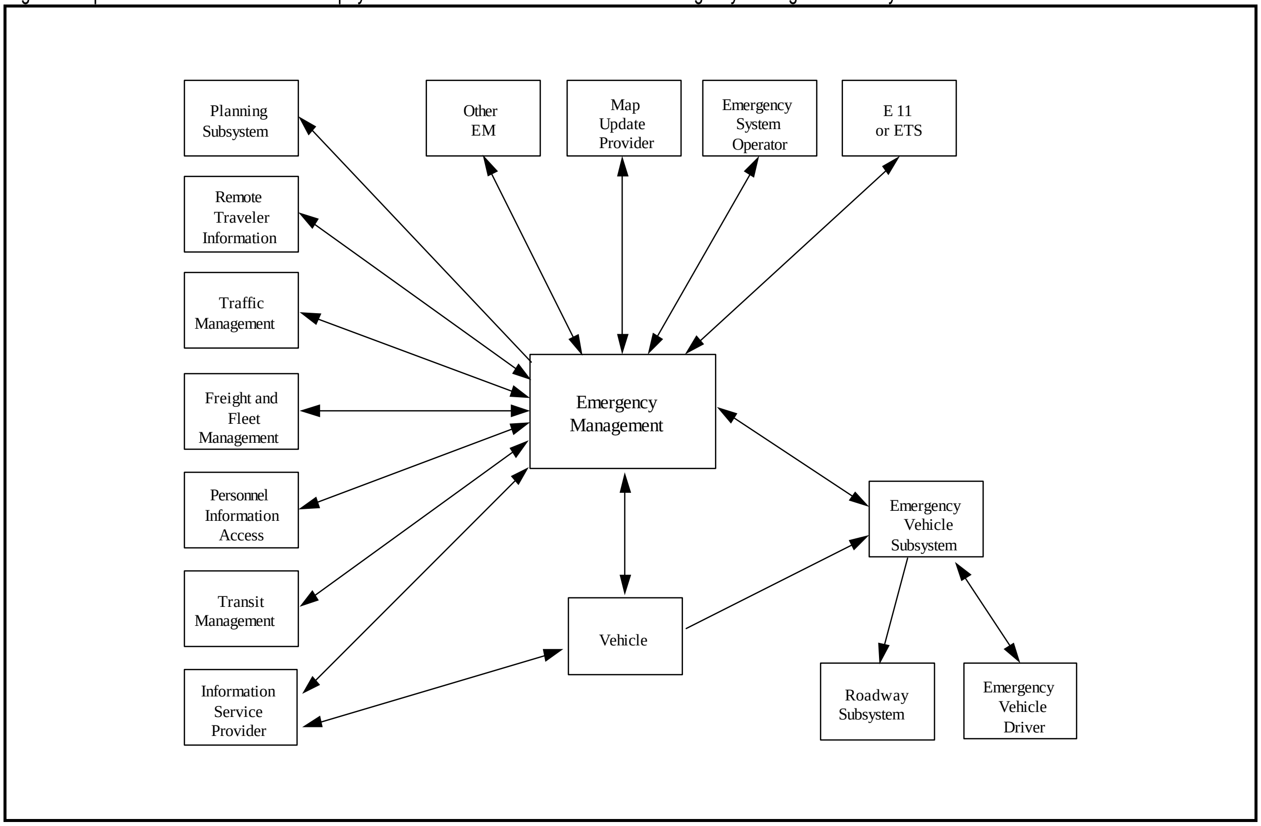

Figure C-2 –Physical Data Flows for Emergency Management

E911 or ETS **->** **Emergency Management**

Physical Architecture Flow Name: *incident information*

Notification of existence of incident and expected severity, location, and nature of incident. Similar information for ERMS, Media, TMS, E911

- Ë Logical Architecture Reference Flow: fets_emergency_telephone_service_identity
- Ë Logical Architecture Reference Flow: fets_incident_details

Emergency Management **->** **E911 or ETS**

Physical Architecture Flow Name: *emergency status*

Status of Mayday requests

- Ë Logical Architecture Reference Flow: tets_incident_acknowledge

Emergency Management -> **Emergency System Operator**

Physical Architecture Flow Name emergency dispatch status

Status indicating location of emergency vehicles dispatched to specified locations

- Ë Logical Architecture Reference Flow: teso_emergency_action_log_output
- Ë Logical Architecture Reference Flow: teso_emergency_vehicle_dispatch_failure

Emergency Management -> **Emergency Vehicle Subsystem**

Physical Architecture Flow Name assigned route

Route provided to vehicle by dispatcher

- Ë Logical Architecture Reference Flow: emergency_vehicle_driver_outputs

Physical Architecture Flow Name emergency dispatch requests

Dispatch information from Emergency Management Center to Emergency Vehicle

- Ë Logical Architecture Reference Flow: emergency_vehicle_driver_outputs
- Ë Logical Architecture Reference Flow: emergency_vehicle_status_data_for_priority

Physical Architecture Flow Name Hazmat information

Information about particular hazmat load including nature of the load and unloading instructions. May also include Hazmat vehicle route and route update information

- Ë Logical Architecture Reference Flow: emergency_vehicle_driver_outputs

Emergency Management -> **Fleet and Freight Management**

Physical Architecture Flow Name Hazmat information request

Request for information about a particular hazmat load

- Ë Logical Architecture Reference Flow: cf_hazmat_request

Emergency Management -> **Information Service Provider**

Physical Architecture Flow Name: emergency vehicle route request

Special routing instructions and signal priority for emergency vehicles

- Ë Logical Architecture Reference Flow: emergency_vehicle_route_request

Physical Architecture Flow Name incident information

Notification of existence of incident and expected severity, location, and nature of incident. Similar information for ERMS, Media, TMS, E911

- Ë Logical Architecture Reference Flow: incident_information

Emergency Management -> **Map Update Provider**

Physical Architecture Flow Name *map update request*

Request for a map update

- Ë Logical Architecture Reference Flow: tmup_request_emergency_display_update

Emergency Management -> **Other EM**

Physical Architecture Flow Name *emergency coordination*

Coordination information between Emergency Management Centers

- Ë Logical Architecture Reference Flow: toec_emergency_telephone_service_identity
- Ë Logical Architecture Reference Flow: toec_incident_details

Emergency Management -> **Personal Information Access**

Physical Architecture Flow Name *emergency acknowledge*

Acknowledge request for emergency assistance and provide additional details regarding actions and verification requirements

- Ë Logical Architecture Reference Flow: emergency_request_personal_traveler_acknowledge

Emergency Management -> **Planning Subsystem**

Physical Architecture Flow Name *operational data*

Statistical data used for planning purposes

- Ë Logical Architecture Reference Flow: emergency_vehicle_operational_data

Emergency Management -> **Remote Traveler Support**

Physical Architecture Flow Name *emergency acknowledge*

Acknowledge request for emergency assistance and provide additional details regarding actions and verification requirements

- Ë Logical Architecture Reference Flow: emergency_request_kiosk_traveler_acknowledge

Emergency Management -> **Traffic Management**

Physical Architecture Flow Name *emergency vehicle greenwave request*

Request for greenwave for emergency vehicle

- Ë Logical Architecture Reference Flow: emergency_vehicle_green_wave

Physical Architecture Flow Name *incident information*

Notification of existence of incident and expected severity, location, and nature of incident. Similar information for ERMS, Media, TMS, E911

- Ë Logical Architecture Reference Flow: incident_details

Physical Architecture Flow Name *incident response status*

Status of currently occuring incident

- Ë Logical Architecture Reference Flow: incident_response_status

Emergency Management –> **Transit Management**

Physical Architecture Flow Name *transit emergency coordination data*

Data exchanged between parties dealing with transit incident

- Ë Logical Architecture Reference Flow: transit_incident_coordination_data

Emergency Management –> **Vehicle**

Physical Architecture Flow Name *emergency acknowledge*

Acknowledge request for emergency assistance and provide additional details regarding actions and verification requirements

- Ë Logical Architecture Reference Flow: emergency_request_driver_acknowledge
- Ë Logical Architecture Reference Flow: emergency_request_vehicle_acknowledge

Emergency System Operator –> **Emergency Management**

Physical Architecture Flow Name *emergency dispatch request*

Operator instructions for dispatch of Emergency Vehicles

- Ë Logical Architecture Reference Flow: feso_emergency_action_log_request
- Ë Logical Architecture Reference Flow: feso_emergency_allocation_override
- Ë Logical Architecture Reference Flow: feso_emergency_data_input
- Ë Logical Architecture Reference Flow: feso_emergency_data_output_request
- Ë Logical Architecture Reference Flow: feso_emergency_display_update_request

Emergency Vehicle Subsystem -> **Emergency Management**

Physical Architecture Flow Name *emergency vehicle driver inputs*

Emergency vehicle driver request for route plan, current status etc.

- Logical Architecture Reference Flow: emergency_vehicle_driver_inputs

Physical Architecture Flow Name *emergency vehicle driver status update*

Additional status information provided by emergency vehicle driver

- Logical Architecture Reference Flow: emergency_driver_status_update

Physical Architecture Flow Name *emergency vehicle tracking data*

Additional emergency vehicle data including status of emergency

- Logical Architecture Reference Flow: emergency_vehicle_tracking_data

Fleet and Freight Management -> **Emergency Management**

Physical Architecture Flow Name *Hazmat information*

Information about particular hazmat load including nature of the load and unloading instructions. May also include Hazmat vehicle route and route update information

- Logical Architecture Reference Flow: cf_hazmat_route_information
- Logical Architecture Reference Flow: cf_hazmat_vehicle_information

Information Service Provider -> **Emergency Management**

Physical Architecture Flow Name *emergency vehicle route*

Routing for emergency vehicle including greenwave paths

- Logical Architecture Reference Flow: emergency_vehicle_route

Physical Architecture Flow Name *incident information request*

Request for incident information, clearing time, severity

- Logical Architecture Reference Flow: incident_information_request

Map Update Provider -> **Emergency Management**

Physical Architecture Flow Name *map updates*

Either static or real-time map updates

- Logical Architecture Reference Flow: fmup_emergency_display_update

Other EM -> **Emergency Management**

Physical Architecture Flow Name *emergency coordination*

Coordination information between Emergency Management Centers

- Ë Logical Architecture Reference Flow: foec_emergency_telephone_service_identity
- Ë Logical Architecture Reference Flow: foec_incident_details

Personal Information Access -> **Emergency Management**

Physical Architecture Flow Name *emergency notification*

Mayday notification by a traveler. Could be on foot, or in any vehicle. Routing is eventually to an Emergency Management Center but may be forwarded by any other organization. Message may contain location and nature of emergency

- Ë Logical Architecture Reference Flow: emergency_request_personal_traveler_details

Remote Traveler Support -> **Emergency Management**

Physical Architecture Flow Name *emergency notification*

Mayday notification by a traveler. Could be on foot, or in any vehicle. Routing is eventually to an Emergency Management Center but may be forwarded by any other organization. Message may contain location and nature of emergency

- Ë Logical Architecture Reference Flow: emergency_request_kiosk_traveler_details

Traffic Management -> **Emergency Management**

Physical Architecture Flow Name *incident information request*

Request for incident information, clearing time, severity

- Ë Logical Architecture Reference Flow: incident_details_request

Physical Architecture Flow Name *incident notification*

Notification of an incident on the roadway through emergency network

- Ë Logical Architecture Reference Flow: incident_alert
- Ë Logical Architecture Reference Flow: incident_response_clear

Transit Management -> **Emergency Management**

Physical Architecture Flow Name *security alarms*

Alarms located in public transit stops or on transit vehicles indicating an incident

- Ë Logical Architecture Reference Flow: transit_coordination_data

- Logical Architecture Reference Flow: transit_emergency_data
- Logical Architecture Reference Flow: transit_incident_details

Vehicle -> **Emergency Management**

Physical Architecture Flow Name *emergency notification*

Mayday notification by a traveler. Could be on foot, or in any vehicle. Routing is eventually to an Emergency Management Center but may be forwarded by any other organization. Message may contain location and nature of emergency

- Logical Architecture Reference Flow: emergency_request_driver_details
- Logical Architecture Reference Flow: emergency_request_vehicle_details

Useful National ITS Architecture Document: Physical Architecture

Appendix D. National ITS Architecture Products

Provided below is a brief overview of all documents that are part of the National ITS Architecture.

Vision Statement Written in "magazine style," the Vision Statement sketches a number of possible scenarios of ITS development over the next 20 years. It describes how travelers and system operators may be able to use and benefit from ITS technologies in their day-to-day activities. While the Vision Statement is not a technical document, it does describe the potential impact of ITS technologies on the management of the nation's transportation system.

Mission Definition The first of the technical documents, the Mission Definition covers a broad range of ITS-related issues. It contains the overall mission of ITS deployment, as well as the operational concept, which deals with specific ITS goals and objectives; ITS user groups and other stakeholders; ITS user services; and potential sources for funding, operations and maintenance. The document also defines operational requirements at the system level, user requirements, performance requirements, and program requirements.

These concepts are important aspects of the National Architecture throughout the deployment process, since they provide the overall direction for the ITS program. Constant evaluation of a region's ITS deployment against the national goals and objectives will ensure that regional ITS deployment is compatible with the philosophy of the National Architecture. The Mission Definition document is important for those that are involved with the initial concepts definition of an ITS system for a particular region.

Logical Architecture The Logical Architecture document contains three volumes: *Description* (Volume 1), *Process Specifications* (Volume 2), and *Data Dictionary* (Volume 3). These documents present a functional view of the ITS user services, contain diagrams that show processes and data flows among them, and define data elements, respectively.

Physical Architecture The Physical Architecture document describes the transportation and communications layers resulting from the partitioning of the processes within the logical architecture, presents architecture flow diagrams that show data passing among physical subsystems, and provides characteristics and constraints on the data flows.

Theory Of Operations This document provides a detailed narrative of the manner in which the architecture supports the ITS user services, described in the Mission Definition. It is a technical document, intended for engineers, operators, and others involved detailed systems design.

Traceability Document The Traceability Document is a technical document that is used in conjunction with and throughout the development of the Logical and Physical Architectures. It lists all the User Service Requirements (USR), which constitute the highest-level functional specifications for ITS, as provided by the U.S. Department of Transportation. In several tables, these USRs are mapped to the various logical and physical components of an ITS system. The document should be used primarily by those involved in detailed design.

Implementation Strategy The Implementation Strategy document ties the elements the National Architecture together, and is intended to assist ITS implementors at all levels with cost-effective, efficient ITS deployment.

Standards Development Plan This document discusses the issues that are involved in the development of system interface standards. It is primarily intended for Standards Development Organizations and system designers, and will be important at the integration step in the Systems Engineering Process.

Standards Requirements This is a set of 12 Standards Requirements Packages that presents detailed data flow and interface information pertaining to the priority standards packages that need to be developed to implement the architecture. It, too, is primarily intended for Standards Development Organizations and system designers, and will be important at the integration step in the Systems Engineering Process.

Evaluatory Design The Evaluatory Design document is intended to evaluate the National Architecture's performance, benefits, and costs for three conceptual scenarios at various points in time. The scenarios consist of "typical" deployment environments: urban, inter-urban, and rural. The entire document will assist you in developing an evaluation methodology for the architecture that you have developed for your particular region.

Communications Document This document provides a thorough analysis of the communications requirements of the National Architecture, and ITS in general, and includes a discussion of options for implementing various communications links. With the latest version of the National Architecture, an addendum to this document was published, detailing requirements for the Highway-Rail Intersections User Service. It is an important document for those involved in detailed design and integration during the Systems Engineering Process.

Risk Analysis This document presents an analysis of potential critical risks that may delay or prevent the deployment of ITS technologies, and recommends mitigation plans which will eliminate of reduce these risks to the deployment process. It is intended for implementors that are involved with the details of ITS deployment in their region, throughout the development of the Regional Architecture.

Cost Analysis The Cost Analysis document has two purposes. First, it develops a high-level cost estimate of the expenditures that are associated with implementing ITS components. Second, it is a costing tool for implementers, by providing unit prices and systems costs of ITS subsystems. There is significant correlation between the Cost Analysis and the Evaluatory Design documents; the Cost Analysis is based largely on the assumptions made for the three deployment scenarios (urban, inter-urban, and rural). The latest version of the National Architecture documents contains an addendum to the Cost Analysis, accounting for the Highway-Rail Intersection User Service. This is an important document for those involved in planning and design, and could be useful to those responsible for project management in the Systems Engineering Process, including funding and procurement.

Performance and Benefits Study This document assesses the technical performance of the National Architecture on a number of system-level and operational-level criteria. It could be helpful in supporting the case for ITS deployment, as it provides a measure of the degree to which ITS can help achieve some regional transportation goals.

Evaluation Results This document contains a concise summary of the various evaluations that were performed in five other National Architecture documents: Evaluatory Design, Communications Analysis, Cost Analysis, Performance and Benefits, and Risk Analysis.

Executive Summary Provides an overview of the most important aspects of the National Architecture, most notably the Logical and Physical Architectures.