Intelligent Transportation Systems

# Building the ITI:

## Putting the National Architecture into Action

U.S. Department of Transportaton

# Building the ITI: Putting the National Architecture into Action

Prepared for the Federal Highway Administration
by Mitretek Systems

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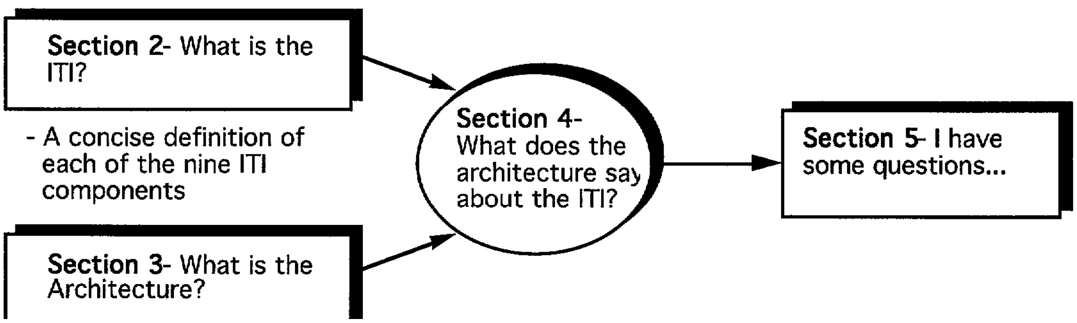
## Purpose of this Handbook

The intended audiences for this handbook are transportation managers, project managers, and their staff. Its purpose is to provide focused information about the National Intelligent Transportation Systems (ITS) Architecture (referred to in this document as the architecture) to those implementing the Intelligent Transportation Infrastructure (ITI) in a metropolitan area. We provide an introduction to what the architecture says about the ITI, and why a planner or implementor should be aware of the architecture. In this handbook, we stay at a fairly high level within the architecture and discuss major architecture systems and information flows...enough to provide a basic understanding of what information the architecture provides to implementors. To go further, the reader needs to refer to the architecture documentation.

In order to make this a standalone document, we have also included some information on what the IT1 components are, what the architecture is, and the benefits of having and using the architecture to guide deployment. We have tried to anticipate potential questions you may have and have included those as questions and answers; these are distributed throughout the document, but are concentrated in Section 5. We hope that these Qs and As provide some insight on key deployment issues.

This is a first generation document that will serve to introduce both public and private sector transportation managers and implementors to the architecture. More detailed implementation guidance is currently being prepared. The following diagram is provided to help you identify sections of this document that you may want to focus on, depending upon your area of interest:




- What is an architecture?
- Why is it important that I know about it?
- How are architecture and standards related?
- What does it mean to "conform" to the architecture?
- What could happen if I ignore the architecture?

- How does the architecture recommend interconnecting the ITI components?
- What architecture subsystems comprise each of the ITI components? (very detailed.)
- What are the integratio needs of the ITI components?

- We've tried to anticipate some questions you may have, such as:

  What do I do until standards are developed?

  What happens to my old equipment?

  Should I let other people use my traffic data?

  Should I lease or buy communication lines?

## 1. Introduction - How this Document will Help You

If you're reading this document, you've probably seen a significant amount of material describing the IT1 (Intelligent Transportation Infrastructure) and discussing the benefits that you can expect from ITI. You've also heard that it's important that you should Buy Smart. But, before you can Buy Smarter, you have to understand the requirements. You'll need transportation systems that integrate with systems of other agencies in your jurisdiction and with those of other jurisdictions. And, you'll need systems that can be readily upgraded to take advantage of constantly improving technologies. At the same time, you have to make the best use of your existing transportation investment and insure that the new systems you add work in harmony with existing equipment.

A significant amount of work has gone into developing the architecture that defines the basic structure of ITS. The architecture will be invaluable in helping you specify, design, and deploy ITS. Used effectively, it will help you build faster, cheaper, and better. The architecture was developed through the joint efforts of a multi-disciplinary group including transportation engineers, planners, communication engineers, and systems engineers. Additionally, a significant effort went into various outreach programs so that the needs of local transportation officials could be factored into the architecture. The architecture contains a wealth of information that will be invaluable as you begin Buying Smarter.

However, the architecture is extensive, technically detailed, and covers a broad range of topics. The full architecture documentation package is approximately 5 100 pages long, covering a number of volumes -- you can't just dive in without getting lost; most people need a roadmap to help understand what the architecture can do for them and how it relates to the material they've seen regarding the ITI. In addition, much of the detail is for systems designers and implementors developing detailed component specifications. This handbook provides an overview and roadmap to the architecture so that you can begin to appreciate how the architecture can help you, without having to examine thousands of pages.

**ITS:**
The application of current and evolving technology to transportation systems and the careful integration of system functions to provide more efficient and effective solutions to multimodal transportation problems. In particular, the technologies and operations needed for a transportation system that will satisfy the requirements of 29 defined user services. These services are listed in Section 3.

**Metropolitan ITI:**
The ITI, formerly referred to as the Core Infrastructure, is the integrated set of nine basic infrastructure components needed to get primarily urban ITS deployment started. The IT1 is the key building block to achieving a fully developed ITS. These are the systems we have to deploy first, and that will lay the foundation for future services. It is envisioned that IT1 deployment will be accomplished primarily by the public sector with support of the private sector. Basically, IT1 is the infrastructure portion of ITS.

**National ITS Architecture:**
The architecture is the framework that addresses the full set of 29 ITS user services. The architecture defines the subsystems and data flows (i.e., information that must be shared between subsystems) required to make ITS work. This handbook briefly summarizes how the architecture can be very beneficial in deploying the ITI.

**But First, Some Background on How we Got Here...**

While research into ITS has been going on for some time, a concentrated Federal program addressing ITS came about with passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in December 1991. The ISTEA established the ITS Program and encouraged implementation of *"A national system of travel-support technology, smoothly coordinated among modes and jurisdictions to promote safe, expeditious, and economical movement of goods and people"*. Attaining a smoothly coordinated system on a national level requires some fairly extensive up-front concept definition and analysis. If jurisdictions are to deploy systems in which vehicles and devices smoothly interoperate, a framework must be developed to guide implementors and manufacturers. This need for a common framework led ITS America to recommend, and the U.S. DOT to initiate, a National ITS Architecture development program. The architecture defines the basic subsystems and interconnections between subsystems required to implement ITS. In addition, it identifies the interface between subsystems for which standards must be developed. The process of developing those standards is underway. By starting with a common framework, the risk of developing systems that are incompatible with one another is significantly reduced. The architecture provides a common framework that should promote national compatibility.

**Standards**

Standards will provide the means by which compatibility between systems will be achieved. The U.S. DOT has initiated an effort to accelerate development of consensus-based standards using the interconnection requirements defined in thr architecture. While these standards are being developed, you can use these same requirements to ensure that your equipment will be reasonably compatible with future systems. You don't have to wait until standards are in place to deploy systems that conform to the architecture.

It was important that all viewpoints be heard as this basic groundwork was laid for future ITS deployment. The architecture was developed with the participation of the private sector, the public sector, academia, national laboratories, and local implementors. The architecture defines the framework for the complete set of anticipated ITS services and represents the collective national view on how ITS should be defined and deployed.

**How is ITI Related to ITS?**

ITS is the full range of services that can be used to improve the performance of users of the transportation system. ITS ranges from traffic control systems to automated highway systems. But you can't start by trying to deploy everything at once. You've got to start with a *core set* of capabilities and do those right. IT1 is that core set of primarily public sector capabilities.

**ITI is a system, not just nine components**

IT1 is an integrated system of transportation components. Each of the nine IT1 components must work smoothly with the others. The architecture has gone to great efforts to exploit the synergies between these components, trying to ensure maximum capability with minimum investment. The initial focus of the IT1 is on urban transportation systems. However, the architecture accommodates Rural and Commercial Vehicle Operations (CVO) systems and details will be forthcoming.

**What Additiodal Guidance Can I Expect from U.S. DOT?**

Over the next several months, U.S. DOT will be preparing guidance documents to help you better understand and utilize the architecture and move forward with system design and procurement actions at regional, state, and local levels. Guidance documents will include:

- Detailed technical guidance on how to deploy IT1 components
- Guidance or functional specifications that will include information needed to ensure future compatibility with newer systems, and that can be tailored to your local requirements
- ITS Planning Documentation (ref. "Interim Handbook on ITS Planning", JHK and Associates, available Spring, 1996)

## 2. What is the Intelligent Transportation Infrastructure (ITI)?

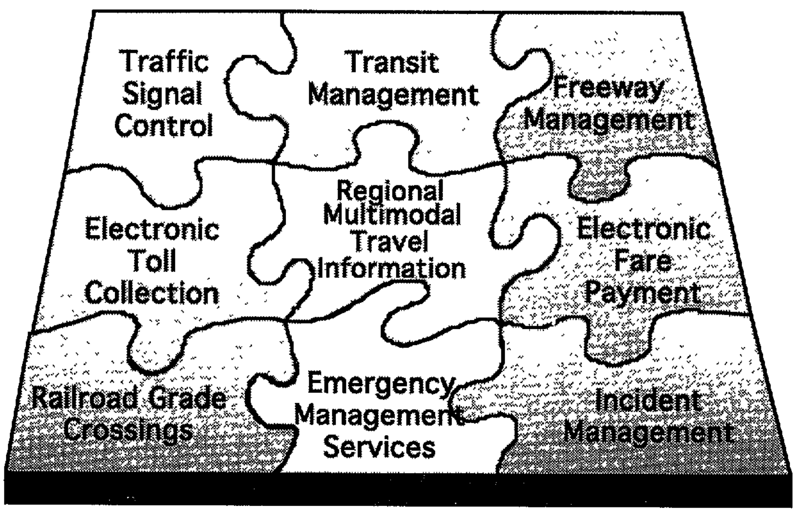
This section discusses what the IT1 is and what the IT1 components do. Later in this handbook, once we understand what the IT1 is, we will get into more specifics as to how the architecture defines how the individual IT1 components function and addresses their integration.

**The IT1 is comprised of 9 integrated components:**

- Traffic Signal Control
- Freeway Management
- Transit Management
- Incident Management
- Electronic Fare Payment
- Electronic Toll Collection
- Railroad Grade Crossings
- Emergency Management Services
- Regional Multimodal Traveler Information

ITI is the infrastructure portion of ITS in metropolitan areas. Many of the functions needed for ITS are already being provided or supported by a broad variety of IT1 features, which can serve as the building blocks of a full ITS implementation. The IT1 refers to those portions of ITS-related hardware, software, services, etc. that today, and increasingly in the future, will manage and support the transportation-related activities. This is typically happening first in metropolitan areas but is expanding to include commercial vehicle and rural needs.

Deployment of the ITI components permits efficient operation and management of roadway and transit resources through the integration and use of currently available technologies, combined with strengthened institutional ties and inter-jurisdictional/interagency coordination. In the near-term, implementation of the ITI components is expected to be led by the public sector, and the development of new and/or enhanced capabilities will occur in an evolutionary manner. This is especially true in the areas of Traveler Information, Electronic Fare Payment, and Electronic Toll Collection. However, private sector participation is highly encouraged, and appropriate partnership opportunities should be actively sought by State and local implementing agencies. Maturation of the IT1 components in metropolitan areas can be expected to drive private sector development of new/advanced products and industries to provide future ITS user services. The ability to upgrade system functions with new system components and technologies in a modular fashion, and the increasing level of integration and coordination of system functions and activities across jurisdictions, agencies, and the various IT1 components, protects investments while enhancing services.




Finally, it must be emphasized that while significant benefits are derived from the nine individual components, even greater benefits can be shown when these features are integrated and operated in a coordinated fashion throughout the metropolitan area or region.

While currently not explicitly mentioned as part of the ITI, Commercial Vehicle Operations (CVO) depends greatly on the services and enhanced performance provided by the ITI. Parallel efforts are being undertaken to encourage enhancement of CVO specific activities which will eventually be incorporated as part of the ITI. Additionally, rural aspects of ITS are also under further development for future inclusion.

The nine IT1 components are described on the following pages.

**Examples of IT1 Benefits:**

Freeway Management Systems, with quantified benefit coming mostly from ramp meters, have reduced accidents by 15% - 62% while handling 8% - 22% more traffic at 16% - 62% greater speeds compared to pre-existing congested conditions

Electronic toll collection allows an increase of 200% - 300% in per lane capacity compared to attended lanes

Transit management systems have yielded improvements in on-time performance of 12% - 28% while reducing costs to yield a positive return on investment in as little as three years

Transit signal priority systems yielded a 5% - 8% decrease in transit run times

Providing a video feed from the traffic management center to the towing concession yielded a clearance reduction of 5 - 8 minutes

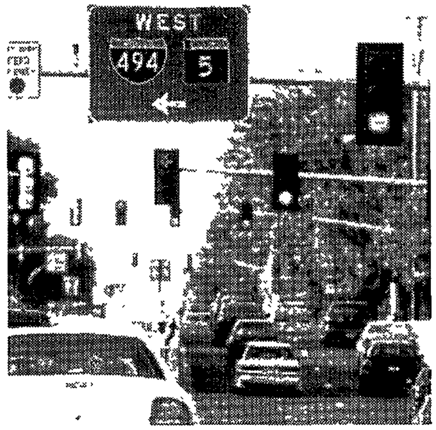
Ref.:

FHWA-JPO-96-001, *Assessment of ITS Benefits: Early Results*

FHWA-JPO-96-008, *Intelligent Transportation Infrastructure Benefits: Expected and Experienced*

## Traffic Signal Control

Signaling systems that react to changing traffic conditions are an important component in improving transportation system efficiency. To be effective, advanced signal control systems require an accurate current picture of the traffic flow and status on the roadway network. This information consists of real-time inputs from traffic sensors (inductive loops, video cameras, etc.), status and incident reports from police and cellular call-ins, etc. Historical demand information, such as time-of-day specific data would, at a minimum, permit the establishment of separate time-of-day signal control strategies. Advanced signal systems automate the use of real-time traffic flow information to change the signal timing to efficiently accommodate traffic demands on all streets.




Current state-of-the-art traffic signal control systems have the capability to dynamically modify signal timings in response to changing traffic demand. They coordinate operation between adjacent signals to maximize the roadway (network) throughput. Coordination of adjacent signals allows the traffic manager to establish timing, in which vehicles can move through selected portions of the traffic network with less delay. At a minimum, these coordinated signal control systems can provide for the selection of several time-of-day or special signal timing patterns that can optimize operations along major arterial routes and over traffic networks. When part of an integrated ITI, traffic signal control can give priority to transit or emergency vehicles. These "open architecture" hardware/software systems are designed to be upgraded in capability, enabling relatively inexpensive installation of improved products. This open architecture approach also supports the potential extension and integration of capabilities, such as coordinated operation with adjacent freeway and arterial systems. The National Transportation Communications for ITS Protocol (NTCIP) is being developed to support interoperability and interconnectivity of traffic control and ITS devices and support capabilities such as variable message sign control, camera control, vehicle classification, and general purpose data collection and device control.

The various signal systems in a region should be capable of electronically sharing traffic flow information with the signal systems of adjoining jurisdictions in order to provide metropolitan-wide signal coordination. This information sharing supports coordination of traffic signal systems along major corridors, and results in smooth traffic flows across jurisdictional boundaries.

**Deployment objectives:**

- Deploy signaling systems that react quickly to changing traffic conditions.
- Collect and process real-time traffic information to provide up-to-date status of the transportation system
- Install automated tools which take al traffic data into account and provide the traffic manager with a clearer picture of the status of the transportation system
- Deploy modular systems that facilitate future upgrades and allow addition of new capabilities as they become available
- Provide flexible signal timing to transit and emergency response vehicles

## Freeway Management

Real-time information about traffic flow and roadway conditions is key to managing the roadway network in a proactive manner. Methods for monitoring freeway conditions include inductive loop detectors, video cameras (with and without signal processing capability), and microwave radar and ultrasonic monitors.

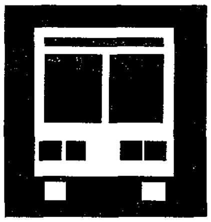
These sensors provide occupancy, presence, count, and in some cases speed and queue length data. Other sources of information on the freeway include the traditional inputs from police and maintenance personnel as well as increasing numbers of cellular phone reports from drivers. Information collected by the Freeway Management component can also be used by the other IT1 components. Relevant information can be made available to support incident management and congestion mitigation activities on the freeway and to allow coordination of these actions with adjacent traffic signal control systems. With video coverage of incidents on the freeway, the incident management team can determine the severity and type of incidents that have occurred and can direct the appropriate resources to the scene. This permits both faster response and better utilization of the incident/emergency response resources, through a tailored response.

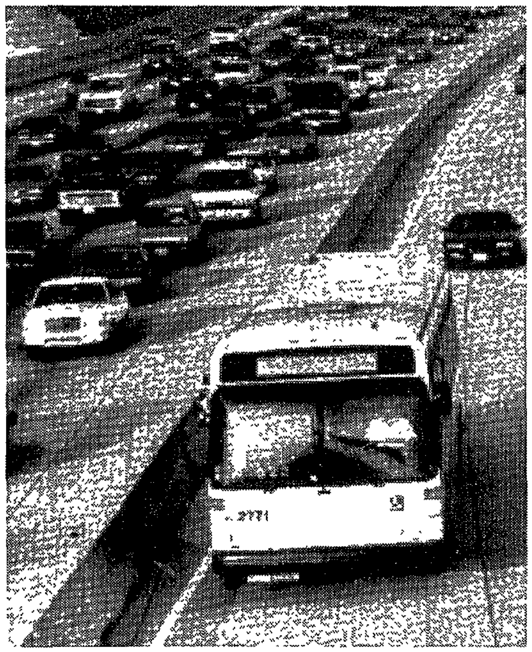
**Deployment Objectives:**

- Provide critical information to travelers through infrastructure-based dissemination methods, such as variable message signs and highway advisory radio
- Monitor traffic and other environmental conditions on the freeway system
- Identify recurring and non-recurring flow impediments so that short-term and long-term actions can be taken to alleviate congestion
- Implement various control and management strategies (such as ramp metering and/or lane control, or traffic diversion)
- Use probe vehicles as an additional sensor for collecting real-time traffic information

The freeway management system(s) include(s) a Freeway Management Center (or multiple centers when responsibility for the freeway system is shared by more than one jurisdiction) and information links to the Regional Multimodal Traveler Information Center and other transportation management and control systems in the metropolitan area. These capabilities can provide, or be enhanced to provide, for the coordination of emergency response and incident management, and to support the management of special-event situations. Examples of integrated/cooperative management include regular analysis and updating of control and incident response strategies and coordination with other local traffic management systems in the area for handling special events.

## Transit Management





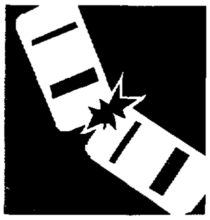
On-time performance is a critical factor in the public's decision to chose transit as a mode of travel. Transit fleet management include hardware/software components on buses and in dispatching centers, radio communications systems, and operations and maintenance facilities and personnel. Depending upon the specific needs of the jurisdiction's fleet management system, additional capabilities could be considered such as automatic vehicle location, advanced voice and data communications, automatic passenger counting, driver information (voice and visual), vehicle diagnostics, geographic information system databases for schedule management and emergency response, as well as computer aided dispatching. These systems reduce cost by improving efficiency, while also providing better information to travelers.

Advanced fleet management systems which include Automated Vehicle Location systems provide reliable bus position information to the dispatcher. The dispatcher with computer assistance can compare the vehicle actual location with schedule information to track schedule adherence and, when necessary, take corrective actions to either get the vehicle back on schedule or to dispatch additional resources to cover the route. This function could be performed manually by the dispatcher or automatically, depending upon the level of automation. In addition, any pertinent schedule information would be disseminated in near-real-time to the traveler, either via kiosks or at home or the office. This information can be used by travelers in conjunction with information from other sources and allows trip planning to include mode selection. The systems can be enhanced to provide a disnlav of information on routes and schedules for transit passengers on the vehicle. Other enhancements include in-vehicle sensors to monitor information such as passenger loading, fare collection, vehicle diagnostics, etc., to support efficient management of the transit system. In the event of an emergency, the dispatcher can notify the police or other support services of the situation and direct the responding authorities to the exact location of the incident. Information links from transit management to and from freeway and signal control functions can be valuable, as when a transit vehicle may require priority at signalized intersections to better meet route schedules.

**Deployment objectives:**

- Provide real-time, accurate transit information to travelers
- Monitor the locations of transit equipment so as to provide more timely information on arrival times
- Optimize travel times for transit vehicles
- Support flexible routing of transit vehicles
- Support automated maintenance monitoring of transit vehicles

## Incident Management



Rapid and effective response to incidents is a key factor in saving lives and reducing travel delay. Many metropolitan areas currently have programs for quickly identifying and responding to incidents that occur on freeways and major arterials. The objectives are to rapidly respond to incidents with the proper personnel and

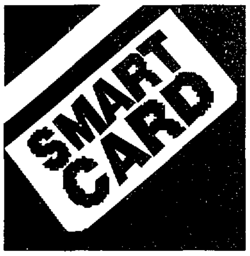
equipment, to aid crash victims, and to facilitate the rapid clearance of the incident from th road-way. Timely execution of these activities saves lives while minimizing the buildup of queues and reducing the delays and frustrations of the traveling public. In this manner the involved public agencies and individuals can satisfactorily meet their requirements and responsibilities. To accomplish incident management, real-time input from the freeway and arterial surveillance systems and the agencies responsible for managing them is critical.

The various jurisdictions and agencies responsible for operations and enforcement in the metropolitan area work together to develop policies and operating agreements that define specific responsibilities for all aspects of incident management, including detection, verification, response, clearance, scene management, traffic control, and information dissemination. These multi-jurisdictional operating agreements ensure routine cooperation, coordination and communications among all agencies, including enforcement, fire, ambulance, highway traffic control and maintenance, environmental (as well as HAZMAT response teams) and other public agencies as well as private towing services. Improved surveillance, augmented by rapid and accurate reporting of incidents, allows the rapid dispatch of appropriate equipment and personnel to the incident scene. Availability of accurate and timely incident information to the traveling public will further help reduce delays for drivers and transit riders. Use of a common regional digital map system by the various traffic and incident management organizations will allow the incident management team to better locate the reported incident, and will facilitate the coordination among the several agencies involved in the incident response.

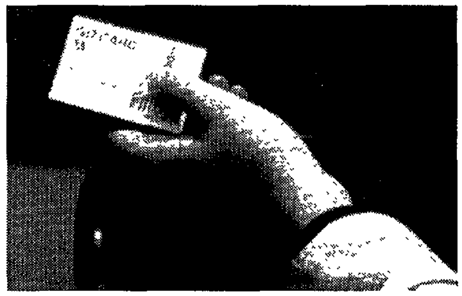
**Deployment objectives:**

- Coordinate incident management across regional boundaries to ensure efficient and sufficient response
- Use traffic management capabilities to improve response times
- Use onboard moving map route guidance equipment to assist incident response vehicles (e.g., ambulances and tow trucks)
- Reduce traveler delays due to incidents

**Electronic Fare Payment**




Electronic fare payment is both convenient for the traveler, who no longer has to fumble for exact change, and a cost savings for public agencies as they reduce manual handling and processing of money.



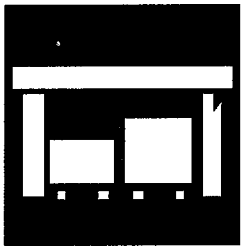
Electronic fare payment systems will be in operation for collection of transit fares, parking lot-fees, etc. The systems will include hardware and software for roadside, in-vehicle, and in-station use, and passenger/driver payment cards, which possibly would include financial and card accounting systems. Electronic fare collection eliminates the need for travelers to carry exact fare (change) amounts and facilitates the subsequent implementation of a single fare payment medium for all public transportation services.

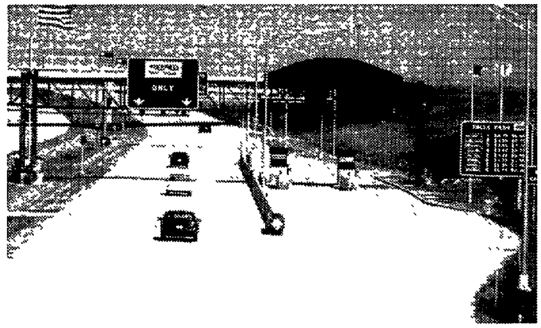
These systems can include debit, credit, and/or stored value cards. Manual cash payment will continue to be supported. Eventually, travelers will be able to use standard financial institution credit cards to pay fares, much as they use a credit card at the gas pump today. Where appropriate, the system would facilitate private company participation in programs where the employer subsidizes employee work-related travel on the transit system by directly depositing funds in employees' transit accounts .

**Deployment objectives:**

- Provide a single medium for paying travel-related fares and parking fees
- Reduce the necessity for travelers and public agencies to handle money

## Electronic Toll Collection





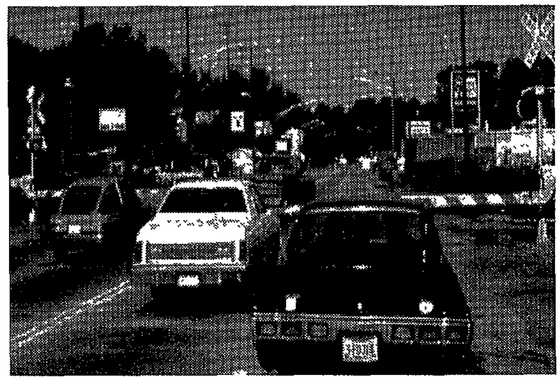

Electronic toll collection reduces delays at toll plazas and operating costs of toll agencies. Electronic toll collection systems are in operation within or around a number of metropolitan areas (and on segments of rural interstate systems) for automated toll collection. The systems include hardware and software for roadside and in-vehicle use, including payment cards or tags, and a communications system between the vehicle and the roadside. Toll payment is processed as the vehicle passes the toll station at a safe speed, thereby decreasing delays and improving system productivity.

The system may include any combination of debit, credit, or stored value toll tag capability. Electronic toll collection systems can be installed in various configurations, including mainline barrier plazas and systems where tolls are based on entry and exit points. Specific functional components-of the system will include automatic vehicle identification, automatic determination of toll amount for differing classes of vehicles, automated enforcement of toll violations and flexibility in financial arrangements (e.g., prepaid debit tag, payment cards).

**Deployment objectives:**

- Reduce delay at toll collection plazas
- Reduce costs incurred by toll operating agency
- Use common toll readers and tags to promote interoperability and reduce cost to the traveling public
- Reduce handling and processing of money

## Railroad Grade Crossings

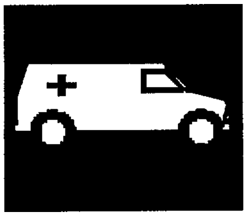
At-grade Railroad Grade Crossings are a special form of a roadway intersection. The fact that one of the roads is a railroad with trains which travel at high speeds and can take up to a mile or more to stop poses special challenges. As a result, automated systems are now becoming available which will allow the deployment of safety systems that adequately warn drivers of crossing hazards. The Railroad Grade Crossing component eventually may support real-time information on train position and estimated time of arrival at Highway-Rail Intersections (HRI), real-time roadway traffic conditions at HRIs, pro-active train control by train control centers, and interactive coordination between roadway Traffic Management Centers and train control centers. The Railroad Grade Crossing component is expected to interface with planned and existing rail automation and safety systems including:

- Advanced Train Control System (ATCS) which interacts with the Central Dispatch System, the On-Board Locomotive System, the On-Board Work Vehicle System, and the Field System. These subsystems are interconnected by a Data Communications System.
- Vehicle Proximity Alerting System (VPAS) which is being tested as a potential communication system between trains and special classes of vehicles (e.g., school buses, large trucks, hazardous materials haulers, and emergency vehicles)
- Remote monitoring systems which will warn local rail dispatchers and/or TMCs of equipment failures at HRIs.

**Deployment objectives:**

- Improve and automate warnings at highway rail crossings
- Provide travelers with advanced warning of crossing closures
- Coordinate rail movements with the traffic signal control system

## Emergency Management Services

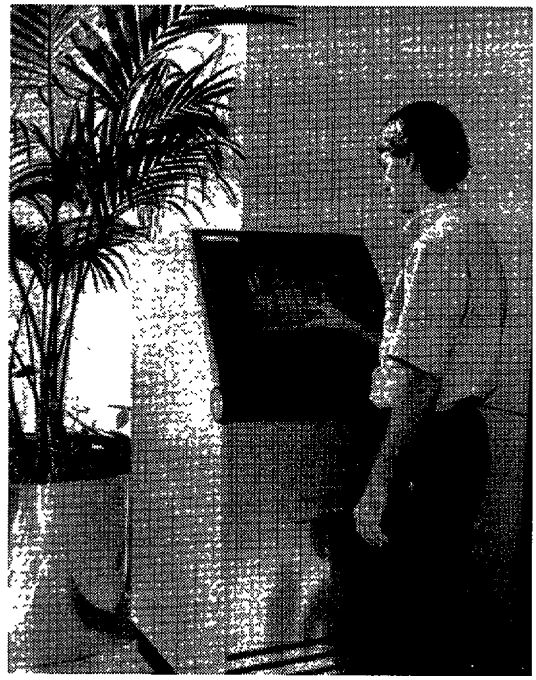


Efficient management and use of emergency equipment is an important contributor to a safe transportation system. By equipping emergency resnonse vehicles with automated vehicle location capabilities, these vehicles can be more efficiently managed by allowing dispatchers to know the locations of various pieces of equipment. Also, this location information can be used to get emergency vehicles to their destinations more quickly. Assignments of response vehicles to cover reported incidents can be based on vehicle location when, for instance, they are not at their station and the routing of these vehicles to the incident scene can be accomplished more effectively based upon accurate knowledge of current vehicle location and traffic condition. Use of a common regional digital map system by emergency services personnel will facilitate the coordination among the several agencies involved in the incident response and will improve the ability to respond to an incident. Emergency management services will also support automated MAYDAY capabilities, a concern in rural areas where accidents may be undiscovered for lengthy periods of time.

**Deployment objectives:**

- Use traffic management capabilities to improve response times
- Use onboard moving map route guidance equipment to assist emergency vehicle operators
- Improve response to HAZMAT incidents by providing emergency personnel with timely, accurate information

## Regional Multimodal Traveler Information



Providing timely travel information will enable the public to make informed transportation choices. Metropolitan areas generally consist of multiple local jurisdictions and state level organizations, each responsible for providing some level of traffic surveillance, management, and control within their own jurisdictions. There is a need for an integrated source of roadway and transit information to provide a comprehensive and integrated view of the roadway and transit conditions throughout the metropolitan area or region. Some users such as travelers, traffic managers and transit operators, and private sector transportation-intensive businesses may use this information directly. Additionally, the private sector may elect to re-package this data and provide it as part of a marketable value-added service.

The information repositories may be either centralized (i.e., housed and managed in one facility) or distributed (i.e., housed and managed in separate facilities) systems that directly receive roadway and transit information from the various roadway surveillance systems and other information sources, either public or private. The IT1 will have the capability to combine the data from the various sources; which allows packaging of the data in a variety of formats and providing the information to the users through different distribution channels, such as telephone voice and data services, radio and TV broadcasts, kiosks, computer-based (e.g., Internet) services, etc. Various options exist for either public or private sector distribution of transportation information.

Traveler information may be provided both directly to the public and to public or private sector Information Service Providers (ISPs) that will supplement it with additional information, features, and services, and market the enhanced service products. Traveler information will be pulled from the various IT1 components into a comprehensive regional information system, thereby facilitating the timely distribution of critical travel-related information to the traveler and transportation-related commercial users.

**Deployment objectives:**

- Promote regional coordination in collecting, processing, and presenting traveler information
- Collect and maintain comprehensive transportation data to all potential users on a timely basis
- Format/package this data such that it will be meaningful to the traveler
- Provide travel information to the public via a range of communication devices (broadcast radio, cellular telephone, the Internet, cable TV) for presentation on a range of devices (home/office computers, television, kiosks, radio)

## 3. The National ITS Architecture and Why it is Important to You

System architecture is a concept that evolved over many years of developing and supporting complex electronic systems. An architecture provides the framework, based on user requirements, for a system design. The architecture identifies basic subsystems, defines the functions performed by each subsystem, and identifies the data that must be transferred between them. It purposely *does not* provide the actual design, however, or tell you what to buy since that is a local choice.

**The 29 User Services Supported by the Architecture**

**Travel and Transportation Management**
- *En route Driver Information*
- Route Guidance
- Travel Services Information
- *Traffic Control*
- *Incident Management*
- Emissions Testing and Mitigation

**Travel Demand Management**
- Demand Management and Operations
- *Pre-trip Travel Information*
- Ride Matching and Reservation

**Public Transportation Operations**
- *Public Transportation Management*
- *En route Transit Information*
- Personalized Public Transit
- Public Travel Security

**Electronic Payment**
- *Electronic Payment Services*

**Commercial Vehicle Operations**
- Commercial Vehicle Electronic Clearance
- Automated Roadside Safety Inspections
- On-board Safety Monitoring
- Commercial Vehicle Administrative Processes
- Hazardous Material Incident Response
- Freight Mobility

**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

Note: Italicized services comprise the basic capabilities of the ITT. Other services build upon them. Highway Rail Intersection is a newlv added user service which will be incorporated into the architecture.

### Why have an architecture?

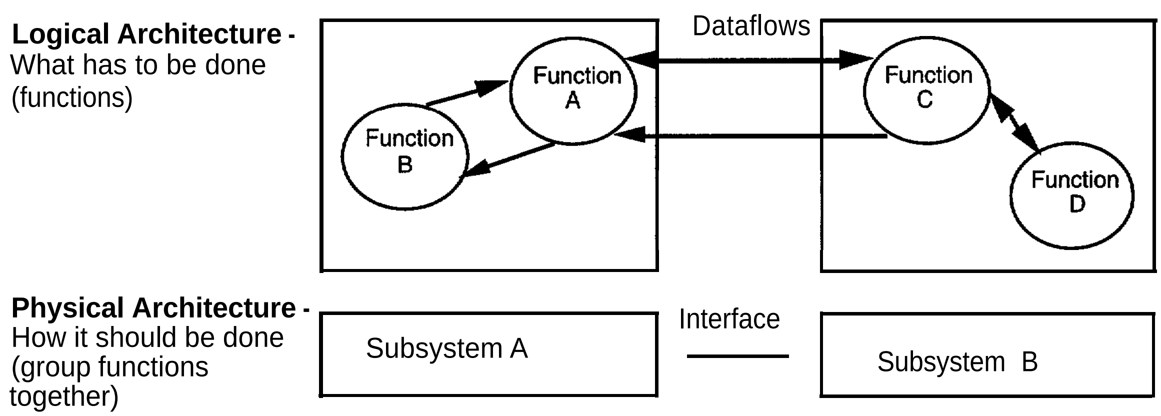
The architecture gives everyone a common starting point and a common language. Every system initially has an architecture. You may not have called it that in the past, but before you did your detailed design, you sat down and decided what the system would do, what its functional components would be, and how these components would be interconnected. That's an architecture.

Transportation system developers in the past did the same thing. Since there was little coordination, everyone's architecture was slightly different, preventing interoperable and interchangeable systems. Now, rather than thousands of localities across the country starting from scratch and developing their own architectures to implement ITS, the architecture gives you a starting point and has gone through much of the up-front analysis for you. You still have to design at the local level, but the architecture moves you ahead several steps in the process and gives you a common framework for discussions with manufacturers and other implementors. The framework is also the foundation for standards development.

**How is the Architecture Structured?**

If you plan to look at the detailed architecture documentation, then you need to be aware of the terminology used and the basic structure of the architecture. At the most fundamental level, the architecture defines a series of functions . These are the various activities that an ITS system would carry out. Examples of functions would be traffic surveillance or operating transit vehicles. Clearly such high-level functions are broad in scope, so they are broken down into more and more detail, yielding sub-functions, sub-sub-functions, etc. Monitor HOV Lane Use or Provide Transit Vehicle Driver Interface are examples of lower level functions defined in the architecture. In the architecture documentation, higher level functions are depicted graphically as Data Flow Diagrams or *DFDs.* Each of the lowest level functions is given a precise definition, known as a Process Specification or *P-spec* for short.

One of the primary roles of the architecture is to assign functions to various components -- or *subsystems* -- of the overall ITS system. Information Service Providers, Traffic Management, and Transit Management are example subsystems. However, the various subsystems cannot act independently of one another. Information about the traffic situation, incidents, etc. must be exchanged between these subsystems if the overall ITS system is to act in a coordinated, integrated fashion. Therefore, the architecture also defines the connections or *interfaces* between these subsystems. This is done in terms of *dataflows.* Probe Data and Transit Fare Information are example data flows.




The Logical Architecture documentation defines the DFDs and P-specs. The Physical Architecture Documentation defines the subsystems, assigns P-spec functions to them, and documents the dataflow interfaces between the subsystems. In this document, the architecture subsystems and dataflows needed to implement IT1 are found in Chapter 4.

**Benefits of Using the Architecture to Guide Deployment:**

- National Compatibility: as travelers and commercial vehicles move within the United States, the equipment on their vehicles continues to support them at all locations
- Multiple suppliers: more vendors will be supplying compatible equipment, leading to competition and less expensive equipment
- Future Growth: By following an "open systems" approach, the architecture allows migration paths for future system growth and expansion (i.e., you upgrade subsystems, you don't start from scratch.)
- Support for ranges of functionality: the architecture supports high-end and low-end features. Basic services can be provided free, while value-added services can be provided on a fee basis.
- Synergy: the architecture considers the requirements for multiple functions and allocates systems to optimally support those functions
- Risk reduction: the architecture's common framework reduces risk for implementors, manufacturers, and consumers alike.

**But my local requirements aren't the same as someone else's...**

The architecture is flexible and doesn't lock you into rigid deployment options. Rather, it addresses all of the subsystems and interfaces that may be required by any IT1 deployment. It is unlikely that any one region would deploy everything. If you don't need a particular subsystem now, you don't have to install it. But, thanks to the architecture, if you later decide that you *do* have a requirement for that subsystem, you can install it without having to replace all of your other equipment *provided* the equipment procured under your initial design conforms to the architecture. That's what we mean by buying smarter . . . you can upgrade or replace parts of your system without having to start from scratch *provided you* have taken care to buy equipment which conforms to the architecture.

## What does "architecture conformance" mean and why is it important?

By conforming to the architecture, we are not talking about a strict, literal, word-by-word adoption of every word and concept documented in the architecture. Rather, we mean you should use the architecture framework to guide you as you design and deploy your systems. In general, by conforming to the architecture, we mean that a subsystem or device:

- Supports the functions defined for that subsystem in the architecture
- Supports the data flows defined for that subsystem in the architecture
- Uses open system interface standards (i.e., uses common communication interfaces supported by industry) wherever they exist, but not to the exclusion of proprietary interfaces or communication protocols with other subsystems when appropriate

**Why is conformance with the architecture important?**

- Following the architecture provides you with an evolutionary path. You won't be stuck with obsolete systems that can't be upgraded.
- The architecture provides a common language for deployment. You want to be in step with current and evolving practices.
- Standards Development Organizations are using requirements from the architecture to develop ITS and IT1 standards.
- Equipment builders are also relying on the architecture's requirements and the standards that are being developed.
- The architecture has already done a lot of work for you in defining data flows and potential system configuration. Take advantage of it!

**Consequences of not conforming to the architecture**

- Future system upgrades (new features or replacements) may be difficult, if not impossible
- You may be locked into one supplier due to proprietary interfaces

## So, is the architecture complete, or is there more work to be done?

At this point in time, the architecture is complete for the list of 29 user services. The architects have taken a first step in trying to map new technologies and new ways of thinking to an old problem. Obviously, changes will have to be made as implementors begin to deploy to the architecture and identify new requirements. For this reason, the U.S. DOT has initiated efforts to ensure that the architecture will be maintained, updated, and distributed as necessary. The specifics of this activity are just now being defined, but we see this as an important activity and we will be seeking input from implementors as part of this process. For example, the Highway Railroad Crossing or Highway-Rail Intersection was not one of the initial user requirements. However, the requirement now exists and plans are being made to add it to the architecture.

## Standards

A major output from the architecture development process is requirements for developing standards. Some ITI/ITS standards development activities are already underway, some are just now in the early development stages. The architecture has identified which interfaces require standardization and has developed initial requirements for those standards. In the interim, between completion of the architecture and development of standards, much of this standards requirements information can be used in designing systems...it's the same information the Standards Development Organizations will be using to guide their standards setting efforts. Your system might not be 100% compatible with the eventual standard, but it will be much easier to make modifications to move into compliance than if you had pursued a totally independent design path. U.S. DOT has already initiated an ITS Standards Development Program which will begin using standards requirements identified in the architecture to develop standards in priority areas. Standards Development Organizations (SDOs) are now on-board and beginning the process of prioritizing and initiating development of these standards. However, standards development is a long process. During this period, U.S. DOT will support an outreach program to keep implementors informed as to what standards are being developed (i.e., news you can use as you design systems) and status as to when key standards will be completed.

**Priority Standards Areas:**

- Information broadcast (e.g., FM subcarrier)
- Travel Information Messages
- Traffic Management (e.g., NTCIP)
- Mayday Messages
- Incident Messages
- Dedicated Short Range Communications
- Commercial Vehicle Operations
- Border crossings
- Map databases

*Note: Priority standards include some that apply to the more general set of ITS User Services , not just strictly to the ITI.

## Architecture Synergies

One of the benefits of the architecture is that it promotes the integration of user services and use of common system components for multiple purposes (e.g., each of the communications channels provides data for multiple user services). As pointed out throughout this handbook, there is significant benefit to having individual subsystems share information with other subsystems. A system designed this way is more efficient and reduces overall cost. Areas where synergy can be found in the architecture include:

1. **Network surveillance.** The information provided from network surveillance equipment (e.g., traffic counts and speeds) can be used for many purposes, including control and management of the traffic signals, incident management, demand management, emissions management, and traveler information (including route guidance). The surveillance information can also be saved as historical data for planning purposes or for evaluating the effectiveness of previous system enhancements. Probe surveillance information can be used for many of the same purposes.

2. **Toll tags.** Vehicles equipped with toll tags can also serve as traffic probes (for flow monitoring). Toll tags could also be used for demand management strategies such as congestion pricing.

3. **Communication channels.** Each of the communication interconnect channels of the architecture is structured to support data messages pertaining to multiple user services. For example, the two-way wide-area cell-based communication system supports messages relating to traveler information, route guidance, emergency notification (Mayday), probe surveillance, yellow pages, etc.

4. **Traffic management subsystem (TMS).** The traffic management subsystem (TMS) allows for many functions to be performed at a single location, enabling the beneficial sharing of equipment, facilities, and information across multiple user services, including traffic control, incident management, travel demand management, and en-route driver information.

5. **Vehicle location determination.** Vehicle location equipment (e.g., a GPS receiver) has many uses within the architecture: vehicle tracking for navigation/route guidance, probe data collection, emergency notification, and personal security.

6. **Map databases.** Map databases in a particular subsystem should be capable of supporting multiple user services. For example, a single map database in a personal vehicle subsystem supports route guidance, en-route driver information, and pre-trip travel information. More importantly for ITI, map databases are an important part of emergency and transit management.

7. **Transit vehicle tracking.** Transit vehicle tracking provides several useful functions: it facilitates more efficient public transportation management (including dynamic route modification and personalized public transit), can provide data useful for travel information purposes (schedule adherence data), and also enhances public travel security (location information can be provided to the police in an emergency or incident).

8. **Electronic fare payment.** A single electronic fare payment media can be used to provide financial transactions for several surface transportation modes (tolls, transit fares, parking charges) as well as non-transportation purposes.

9. **CVO tag/DSRC.** A tag and Dedicated Short Range Communication (DSRC) system on board commercial vehicles can support multiple services, such as electronic clearance, international border clearance, and safety monitoring.

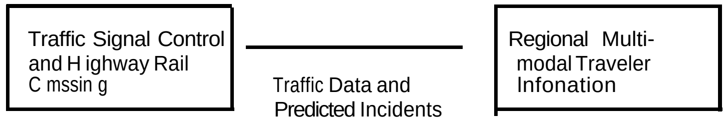
## 4. How the Architecture Addresses the ITI

Up to this point, we have defined the IT1 components, discussed what the architecture is, and discussed why it is important that the architecture be utilized in deployment. In this section, we pull just enough information from the architecture definition to show you what the architecture says about how the IT1 works.

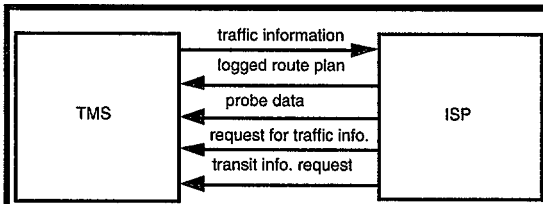
The architecture documentation is a highly detailed set of technical documents. The definition portion of the architecture was written by engineers for engineers. This illustrative diagram shows how just one of the simple objects in our handbook can be blown up into extensive detail in the architecture definition.

What we have done in this document is gone through the architecture definition and pulled out the basic subsystems and data flows that are needed to implement the ITI. In some cases, we have taken liberties in combining numerous data flows into single, generic data flows. This is enough to get you started as you begin to understand how to use the architecture.

This type of picture in this hand book




Translat es in to the fo llow ing in the a chitecture




**traffic information** - a physical architecture flow containing the following logical architecture references
current_road_network_data
traffic_data_media_parameters
predicted_incidents
prediction_data
retrieved_incident_media_data
map_data_for_traffic_display
traffic_data_for_media
incident_data_output

incident data output - a logical reference

definition.

This data flow is used within the Manage Traffic function and contains incident data that is to be output by the Media System. This data will cover a particular current or predicted incident, rather than the output of more general incident information, as the Media System is expected to be something similar to the current Highway Advisory Radio systems The data must also specify the part(s) of the Media System that are to output the data so that it can be directed to the appropriate areas.

Functional Requirements Process(es).

| source | sink |
|---|---|
| **1.3.4.1** | **1.3.4.5** |

Functional Requirements Process(es) definition

**1.3 Manage Incidents:**

These processes are responsible for the detection, recording, and managing of both predicted and current incidents which will affect the traffic flow and service provided to the traveler.

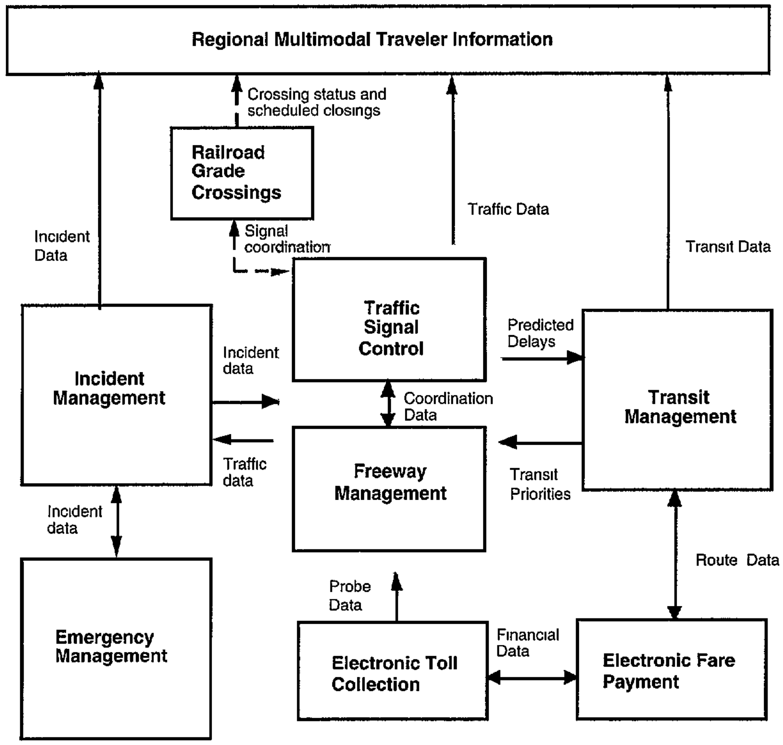
**1.3.4 Provide Operator Interface for Incidents:**

These processes provide an interface through which the Traffic Operations Personnel can review and update data about incidents The processes also provide facilities that enable a "sanitized" output of data on current and predicted incidents to be produced for use by the Media in its dissemination of traffic related Information

**1.3.4.1 Retrieve Incident Data:**

This process retrieves incident data on request from the data stores managed by other processes in the Manage Incidents facility of the Manage Traffic function Requests may come from Traffic Operations Personnel or the Media Operator. The Output is returned to the source of the request, except where the Media Operator has specified that the output should got to the Media System

This is a simplified diagram of the ITI components and their basic interconnections, as they are defined in the architecture. The boxes are the ITI components that you've seen discussed earlier in this document. The arrows and the words beside them represent the types of data that will have to be communicated between the components. This definition of data content and direction of transfer constitutes an interface. The arrows indicate the direction where the bulk of the data for that interface will travel. (In strict technical terms, almost all interfaces are two-way in that the computer systems involved have to talk back and forth in order to accomplish a transfer of data. There are some rare exceptions.) For two-way arrows, a substantial amount of data must move back and forth across the interface.




Note that two of the ITI components (Traffic Signal Control and Freeway Management) are grouped together in a larger box. This is done for two reasons: First, these two components

**Basic ITI data flow definitions:**

**Incident Data**: location, severity, and type of incident

**Traffic Data:** current status and predicted conditions of the road network

**Transit Data**: transit routes, schedules, services, estimated arrival times at transit stops and destinations, and deviations from published schedules and routes.

**Coordination Data:** coordination data may include signal timing plans and ramp metering parameters

**Predicted Delays:** link delay, queue delay, and occupancy predictions for links of the road network

**Transit Priorities:** signal priority/pre-emption, ramp priority/pre-emption

**Probe Data:** journey times for equipped vehicles between readers at toll collection and other points

**Route Data:** transit routes, services, and timings

**Financial Data:** transit fares, vehicle and credit IDs, toll segment information, and confirmations of advanced payment

**Crossing Status and Scheduled Closings/Signal Coordination:** To be determined require essentially the same types of interfaces to the other IT1 components; this is emphasized by having the arrows go to the outer box. They also share data with each other, as shown by the Coordination Data arrow between them. Second, the architecture provides the flexibility to implement these two components separately or to combine them into a single facility. As we move further through Section 4, we will define each of the IT1 components individually. For each component, a diagram will depict the architecture subsystems that make up that component and will show the data flows defined in the architecture required to interconnect those subsystems. The definitions for the subsystems and some discussion of the data flows will be provided. To obtain more data on those subsystems or components, it will be necessary to dig into the architecture.

**The Integrated IT1**

The following paragraphs step you through the boxes and arrows shown in the IT1 system diagram on the previous page. Starting at the left side of the diagram are two tightly coupled components: Incident Management and Emergency Management. Incident Management also has interfaces with the Regional Multimodal Traveler Information and Traffic Signal Control/Freeway Management components. Incident Management receives traffic data from the Traffic Signal Control/Freeway Management components whenever there is an indication of the possible presence of congestion. These data include such information as vehicle counts, queue lengths, and speeds. Incident Management analyzes these data for incidents. If the system detects an incident, the appropriate Incident Management functions are carried out. This includes passing the location of the incident on to the Emergency Management component, if appropriate. Emergency Management will dispatch the appropriate vehicles to the scene. Details on the incident and the response status are passed back in the reverse direction from Emergency Management to Incident Management. In addition, details on the location, time, type, and severity of the incident are passed to Regional Multimodal Traveler Information and Traffic Signal Control/Freeway Management. Information on predicted incidents, such as planned lane closures, is also passed. For Regional Multimodal Traveler Information, incident data are supplemented with information on the impact on traffic. Incident data passed back to Traffic Signal Control/Freeway Management enable signal timings to be adjusted to allow green waves for emergency vehicles responding to the incident. Incident data also serve as the basis for generating messages displayed on Variable Message Signs (VMS).

Transit data are transferred directly by the Transit Management component (shown on the right side of the diagram) for use by Regional Multimodal Traveler Information. There are two basic types of Transit Data. The first type is relatively static (i.e., does not change rapidly over time.) It includes information on transit routes, schedules, and services. Clearly, such information does not have to be exchanged on a minute-by-minute basis. The second type of Transit Data is quite dynamic and includes estimated arrival times at transit stops and destinations, and deviations from published schedules and routes.

Transit Management generates data for its own operation and makes it available to the Regional Multimodal Traveler Information component for dissemination to the traveling public. It is responsible for packaging the data and disseminating it to the public in a variety of formats. For example, the route number of an approaching transit vehicle can be displayed on electronic signs at roadside transit stops. Interactive kiosks and personal hand-held devices can receive the data for use in trip planning, or the information can be broadcast over a wide area by an Independent Service Provider. This division of responsibility between Transit Management and Regional Multimodal Traveler Information is illustrative of how the architecture assigns functional responsibility and why the various

IT1 components must be integrated to provide maximum benefit. It also illustrates the regional variations allowed while still conforming to the architecture.

Traffic Signal Control/Freeway Management, shown at the center of the figure, are the hub of the ITI Both of these components are responsible for the surveillance, monitoring, device control, and management of the road network. Each passes traffic data to the Incident Management and Transit Management Components. These data include link travel times, traffic volumes, and speeds currently flowing on the road and highway network. Model predictions for these quantities may also be included. The traffic data are also output to Regional Multimodal Traveler Information. There they are disseminated to the public for trip planning and other purposes.

The Traffic Signal Control/Freeway Management components monitor the current traffic situation through surveillance equipment and through receipt of incident data. A portion of this information is passed on to Transit Management in the form of predicted delays along various portions of the road network. Transit Management needs these data to manage transit vehicle schedule deviations and generate the necessary corrective actions such as the introduction of extra vehicles or the premature termination of some services. It would be inefficient for Transit Management to duplicate the collection of raw traffic data and generate the delay information. Again, by integrating IT1 components, the architecture enables Transit Management to take advantage of the available information in another component.

Information also flows in the reverse direction -- from Transit Management to the Traffic Signal Control/Freeway Management components. This takes the form of Transit Priorities. Static priority data is passed from Transit Management to Traffic Signal Control. This establishes the overall transit priority on the roadway. Real-time priority data is also passed. Originating within transit vehicles, these data allow Traffic Signal Control to adjust traffic signals. Priority or even signal preemption is given to transit vehicles in accordance with the overall management philosophy.

Similar static and dynamic priority data are also passed from Transit Management to Freeway Management. This allows ramp control signals to be adjusted in accordance with an overall transit ramp management philosophy.

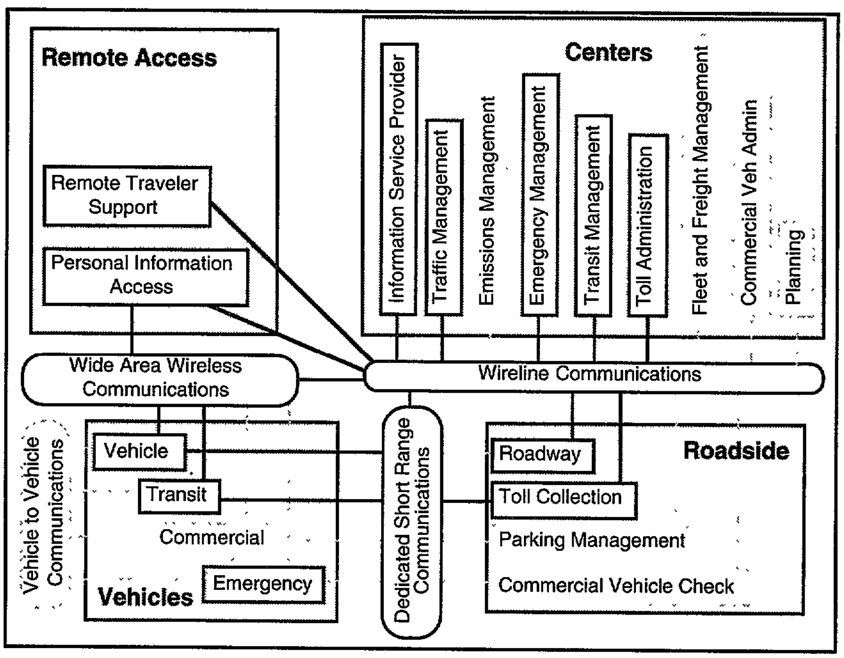
The Traffic Signal Control/Freeway Management components also exchange Coordination Data with each other as shown inside the larger box. The Coordination Data flow allows the traffic management strategies on the freeways, the freeway entrance ramps, and the surface street network to act as an integrated system. These data define the actions to be taken by the system when a particular signal timing plan is in effect on the road network, and when a particular sign plan is in effect on the highways. For example, ramp meter timings and traffic signal controls can be coordinated to ensure that queues do not back up into intersections. Or consider a scenario in which traffic is being diverted off of a freeway to bypass an incident. Traffic signal timings can be adjusted to handle the increased flow on the arterials. At the same time, variable message signs can be updated along the arterials to give directions on how to return to the freeway beyond the incident location.

Electronic Toll Collection is responsible for automatic collection of tolls so that motorists do not have to stop to pay them. Although this offers significant benefits as an isolated system, there is further synergism obtained by integrating Electronic Toll Collection with other IT1 components. In particular, the Electronic Toll Collection roadside and vehicle electronics can be used as a source of traffic probe data for Traffic Signal Control/Freeway management components.

Financial Data may be transferred between the Electronic Toll Collection and Electronic Payment components. These data facilitate intermodalism. Advanced payments are made and then converted to either fares or tolls as the travelers' need arises. Without this interface between the Electronic Toll Collection and Electronic Payment components, travelers would have to maintain separate accounts for tolls, transit fares, and parking. The goal is to be able to use a standard credit card, much as is being done in many supermarkets or at gas pumps.

The Regional Multimodal Traveler Information ITI component is the most visible one, in that it provides information to the public. It receives incident, traffic, and transit data from the other ITI components. Multiple jurisdictions and agencies are involved in this process. The data are combined to provide a region-wide, multi-modal information stream for dissemination to the public. A variety of electronic media can be used to get information to travelers and businesses, ranging from radio and TV broadcasts and transit kiosks, to subscriber information via personal devices. While much of ITI is public sector deployment, Regional Multimodal Traveler Information presents opportunities for private sector Information Service Providers.

## The "Sausage Diagram"




This diagram (Courtesy of the Rockwell/Loral Architecture team), is referred to by the architects as the "sausage diagram" (due to the shape of the communication linkages. It depicts the 19 subsystems for the full ITS and shows the basic communication channels between these subsystems. The highlighted subsystems (i.e., in boxes with bold outlines, such as Remote Traveler Support) represent the subset which support the ITI.

The basic communication links are:

- Wide area wireless - this link provides direct two-way contact between a vehicle and an infrastructure-based subsystem. It may be supported by cellular communication or Specialized Mobile Radio and could be used to provide real-time traveler information to travelers in moving vehicles, scheduling and status information to and from transit vehicles, etc.

- Wireline communications - this is something like plugging your computer modem into your telephone outlet and connecting to an on-line service. There are ranges of capacity for wireline communication, they may be dedicated or dial-up, and they may be provided by either the public or private sector. In some cases, it may actually use wireless links (e.g., microwave), but the two ends are always fixed.

- Dedicated Short Range Communications (DSRC) - This channel would be dedicated for short range (up to about 200 feet) communication between vehicles and the immediate infrastructure. It would support functions such as toll collection, transit vehicle management, or automated commercial vehicle operations.

Each of the nine ITI components is associated with one or more of the 19 architecture subsystems. The following table illustrates this affiliation between the IT1 and the architecture. The question mark under Railroad Grade Crossings indicates that this interface has not yet been defined.

| Architecture Subsystem \ ITI Component | *Traffic Signal Control* | *Freeway Management* | *Transit Management* | *Incident Management* | *Electronic Fare Payment* | *Electronic Toll Collection* | *Railroad Grade Crossing* | *Emergency Management* | *Regional Multimodal Traveler Information* |
|---|---|---|---|---|---|---|---|---|---|
| Commercial Vehicle Administration (CVAS) | | | | | | | | | |
| Commercial Vehicle Check (CVCS) | | | | | | | | | |
| Commercial Vehicle Subsystem (CVS) | | | | | | | | | |
| Emergency Management (EM) | | | | | | | | x | |
| Emissions Management (EMMS) | | | | | | | | | |
| Emergency Vehicle Subsystem (EVS) | | | | | | | | x | |
| Fleet and Freight Management (FMS) | | | | | | | | | |
| Information Service Provider (ISP) | | | | | | | | | x |
| Personal Information Access (PIAS) | | | | | | | | | x |
| Parking Management (PMS) | | | | | | | | | |
| Planning Subsystem (PS) | | | | | | | | | |
| Roadway Subsystem (RS) | x | x | | | | | x | | |
| Remote Traveler Support (RTS) | | | | | x | | | | x |
| Toll Administration (TAS) | | | | | | x | | | |
| Toll Collection (TCS) | | | | | | x | | | |
| Traffic Management (TMS) | x | x | | x | | | ? | | |
| Transit Management (TRMS) | | | x | | x | | | | |
| Transit Vehicle Subsystem (TRVS) | | | x | | x | | | | |
| Vehicle (VS) | | | | | | x | | | |

## Architecture Deployment Strategy

The logical and physical architectures that have been discussed above are provided to describe how transportation functions and data flows are tied together. They do not provide any guidance as to which organizations should provide the functionality. If one organization carries out multiple functions and operates multiple sub-systems, this is all to the good, because that organization can more likely ensure that data flows are compatible.

However, one of the benefits of the ITS architecture is that it identifies what data flows might exist between different organizations, such as transit management and traffic management organizations. The architecture indicates the requirements for each organization's functions to be able to be coordinated or integrated with those of another entity. For example, traffic surveillance could be carried out by a private sector entity as well as by the more traditional public agencies because the architecture defines the links needed to cross both jurisdictional and organizational boundaries.

The ITS architecture identifies portions of the physical architecture as one or more Information Service Providers, or ISPs. The ISPs provide transportation information to travelers and other interested users. The important point of the architecture is that an ISP can be either a public or private organization. For example, a State or municipal traffic agency could collect, process and disseminate traffic information; or, the traffic agency could collect and process the data, and then provide (perhaps even sell) it to a private ISP that would do more sophisticated processing, and then sell it to consumers. Other variations can exist, where a commercial ISP would obtain raw data directly from local traffic sensor/processor systems.

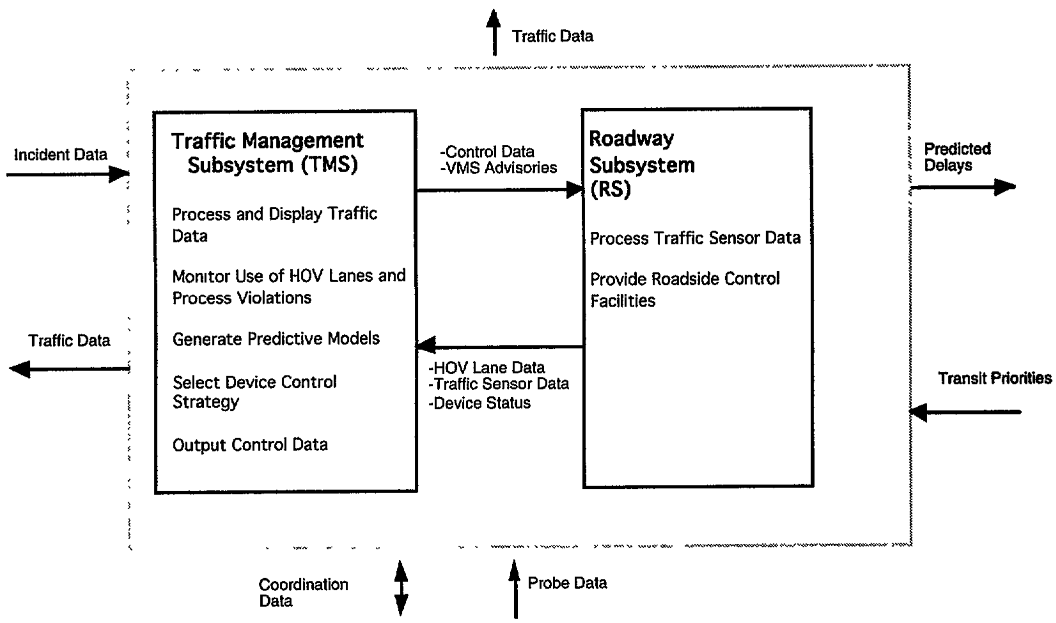
The architecture has a structure that allows for any and all of the possible ISP arrangements. The data flows have been identified in such a way that the organizations involved in a particular deployment approach can find the appropriate assistance in the architecture documents.

### What the following paragraphs provide

The following paragraphs provide more architecture information on the individual IT1 components. Architecture subsystems that make up the IT1 components are shown. Data flows between these subsystems are also shown. Note, however, that these flows are *internal* to and reside within the IT1 component. The *external* flows to other components were discussed in the preceding section. They are indicated here as external to the outer dotted line boxes surrounding the subsystems.

## Traffic Signal Control

Traffic Signal Control is responsible for control of coordinated signal systems along urban arterials and networks. Its functions are assigned to two architecture subsystems--Traffic Management Subsystem (TMS) and the Roadway Subsystem (RS). Sensor data is input by the Roadway Subsystem. In configurations where control is at least partially handled centrally, this data is passed to the Traffic Management Subsystem for processing. There the traffic situation is analyzed, displayed, and the appropriate control strategy selected. This information is then passed back to the Roadway Subsystem where device control takes place. The Roadway Subsystem also receives the data that allows transit or emergency vehicles to receive priority or pre-emptions at traffic signals.




### Traffic Signal Control Flows

**Control Data:** depending on the configuration, will either be the actual indication seen by the driver (e.g., red light), a fixed timing plan, or instructions to use local intelligence

**VMS Advisories:** the textual information displayed on VMS signs

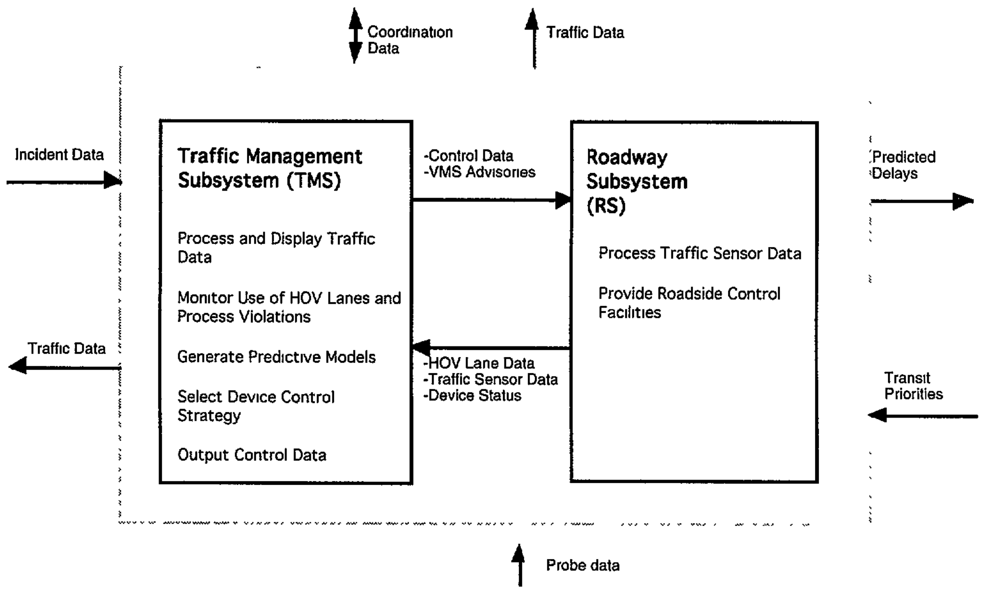
**HOV Lane Data:** data from which use of HOV lanes can be monitored; includes vehicle counts, number of lane-usage violators, and video images

**Traffic Sensor Data:** data obtained from processing surveillance inputs; includes such items as video images, speeds, and queue lengths

**Device Status:** fault data including indicator identification and type of fault and status data, such as the current phase of a traffic signal

### Freeway Management

Freeway Management has the same functions as Traffic Signal Control, but is responsible for managing traffic on highways. The same functional allocation to the architecture's Traffic Management and Roadway Subsystems takes places as in Traffic Signal Control. In fact, the architecture provides the flexibility to combine these two ITI components into a single physical facility.




**Freeway Management Data Flows**

**Control Data:** depending on the configuration, will either be the actual indication seen by the driver (e.g., red light), a fixed timing plan, or instructions to use local intelligence

**VMS Advisories:** the textual information displayed on VMS signs

**HOV Lane Data:** data from which use of HOV lanes can be monitored; includes vehicle counts, number of lane-usage violators, and video images

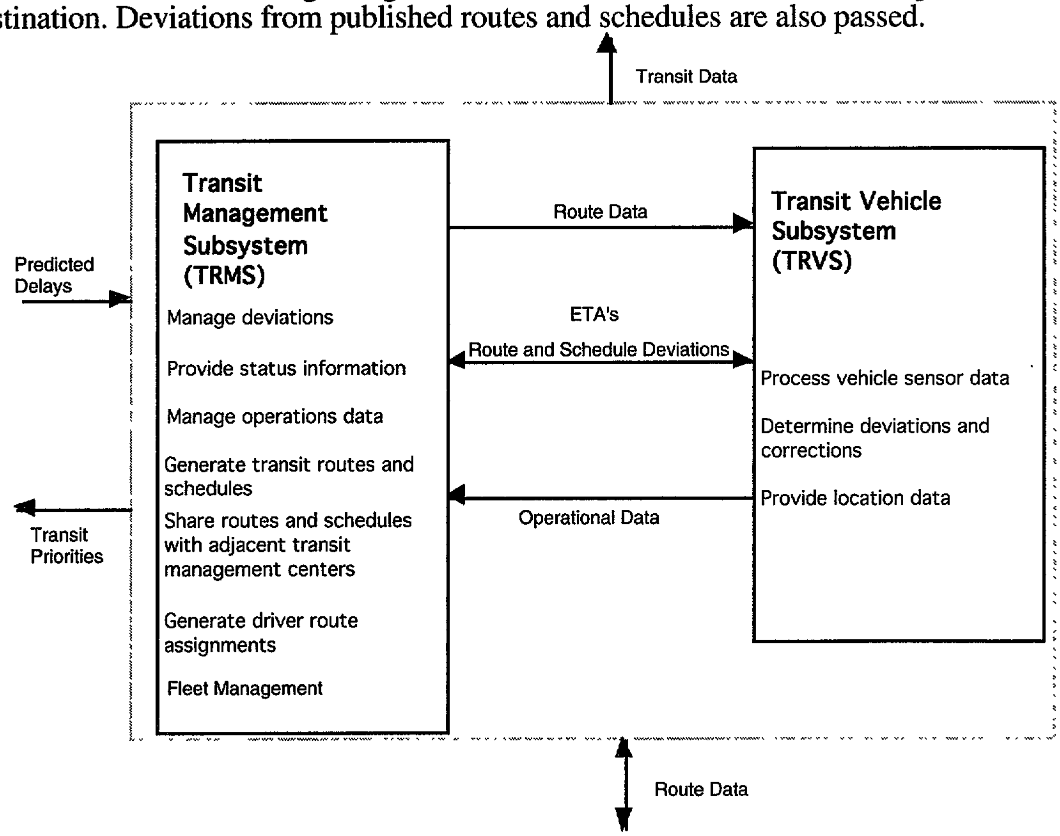
**Traffic Sensor Data:** data obtained from processing surveillance inputs; includes such items as video images, speeds, and queue lengths

**Device Status:** fault data including indicator identification and type of fault and status data, such as the current phase of a traffic signal

## Transit Management

Transit Management comprises two subsystems from the architecture. The Transit Management subsystem (TRMS) is responsible for managing the overall transit system. It uses current dynamic data to carry out immediate functions, such as managing route or schedule deviations. It also uses more static data for such functions as generating routes and schedules. Electronics on the transit vehicle are contained in the Transit Vehicle Subsystem (TRVS). This subsystem allows the vehicle to communicate with other ITS components. It also includes sensors to determine vehicle location. This information is needed for vehicle tracking by the Transit Management subsystem and for electronic fare determination by the ITI Electronic Payment component.

Several data flows are needed between the two subsystems in order to implement the ITI Transit Management component. Route Data, which contains information on routes and services is passed from the Transit Management subsystem to the Transit Vehicle Subsystem. In the reverse direction, the Transit Vehicle Subsystem outputs information on passenger loading, vehicle operating conditions, and vehicle location. Information is passed in both directions regarding the estimated time of arrival at transit stops and at the destination. Deviations from published routes and schedules are also passed.




**Transit Management Data Flows**

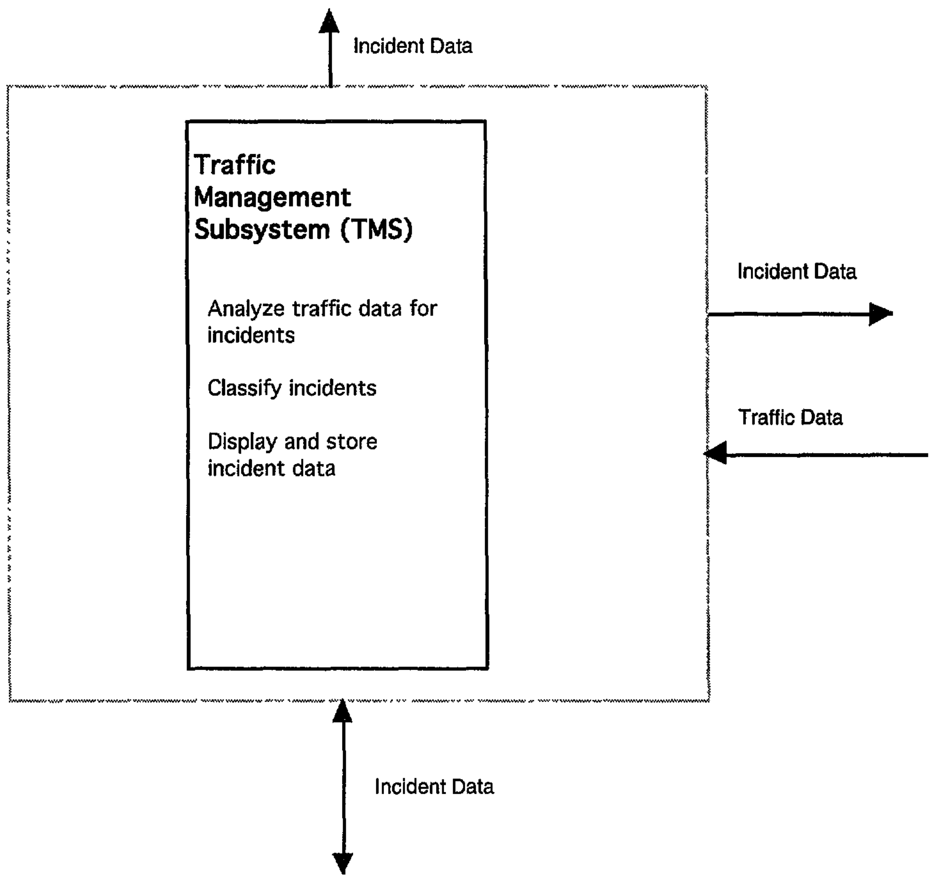
**Route Data:** route numbers, list of route segments, list of stops along the route, ETAs

**Route and Schedule Deviations:** deviations from scheduled route, deviations from time schedule, deviation from published service

**Operational Data**: passenger loading, vehicle operating conditions, transit vehicle locations

## Incident Management

Incident Management functions are assigned to a single architecture subsystem--the Traffic Management System. This subsystem also has important roles in Traffic Signal Control and Freeway Management. The Traffic Management Subsystem analyzes the traffic data that it has available in carrying out these other roles. If an incident is detected, its location, type, and severity are determined. In accordance with a response plan stored at the Traffic Management Subsystem, the Emergency Management component is alerted to the incident using these details. Private towing and recovery companies are usually responsible for incident clearance.

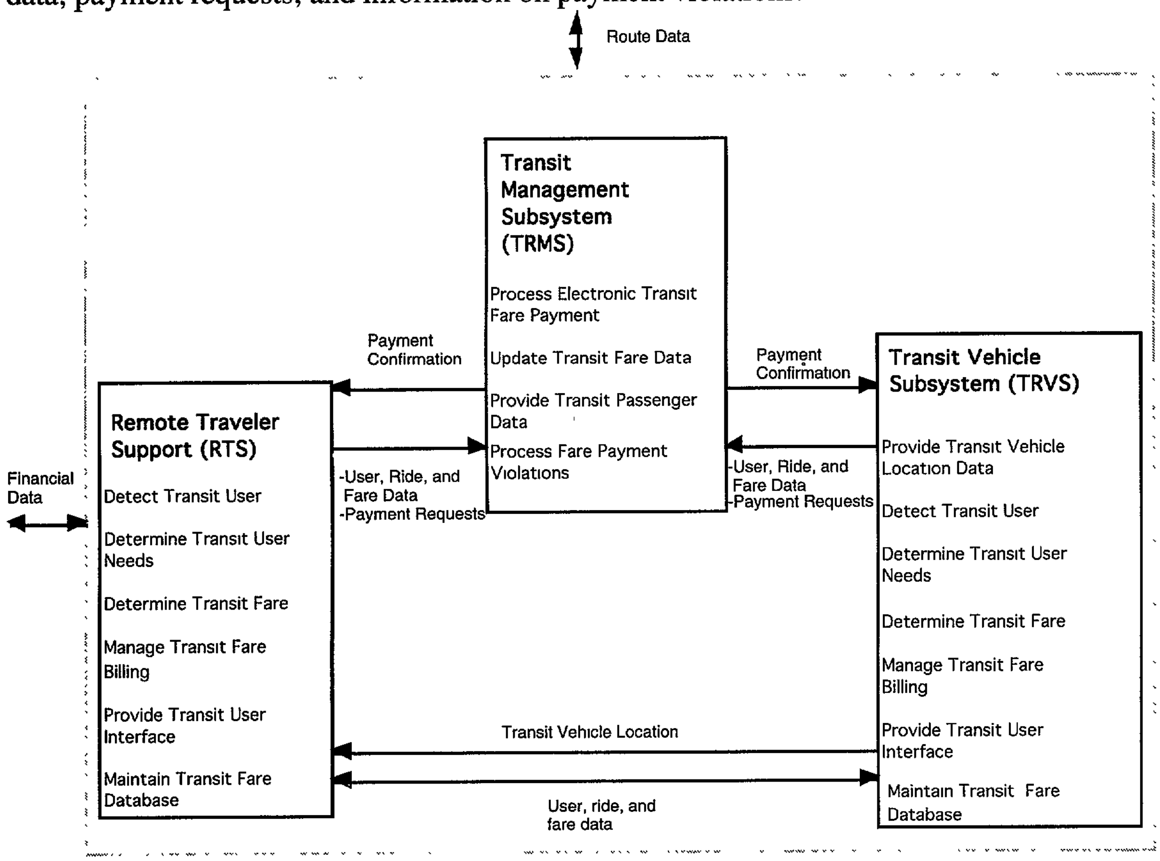



**Incident Management Data Flows**

Since Incident Management is represented by a single subsystem within the architecture, there are no internal dataflows for the Incident Management Component.

## Electronic Fare Payment

Three architecture subsystems make up the Electronic Fare Payment component. The Transit Management subsystem (which is also part of the ITI Transit Management component) receives payment requests from the Remote Traveler Support (RTS) and the Transit Vehicle Subsystem (TRVS), processes payment information, and provides payment confirmation replies. The RTS and TRVS subsystems are where travelers interact with ITI and make their payments. They essentially duplicate each other's functionality. RTS allows payment to be made at fixed locations such as transit stations, event centers, and business locations. TRVS allows payment to be made on board the vehicle. TRVS also has one additional function, providing transit vehicle location data. This, in conjunction with the travelers destination, is needed to make a fare determination. RTS and TRVS provide essentially the same types of information to TRMS, namely user, ride, and fare data; payment requests; and information on payment violations.




**Electronic Fare Payment Data Flows**

**Payment Confirmation:** confirm transit fare payment

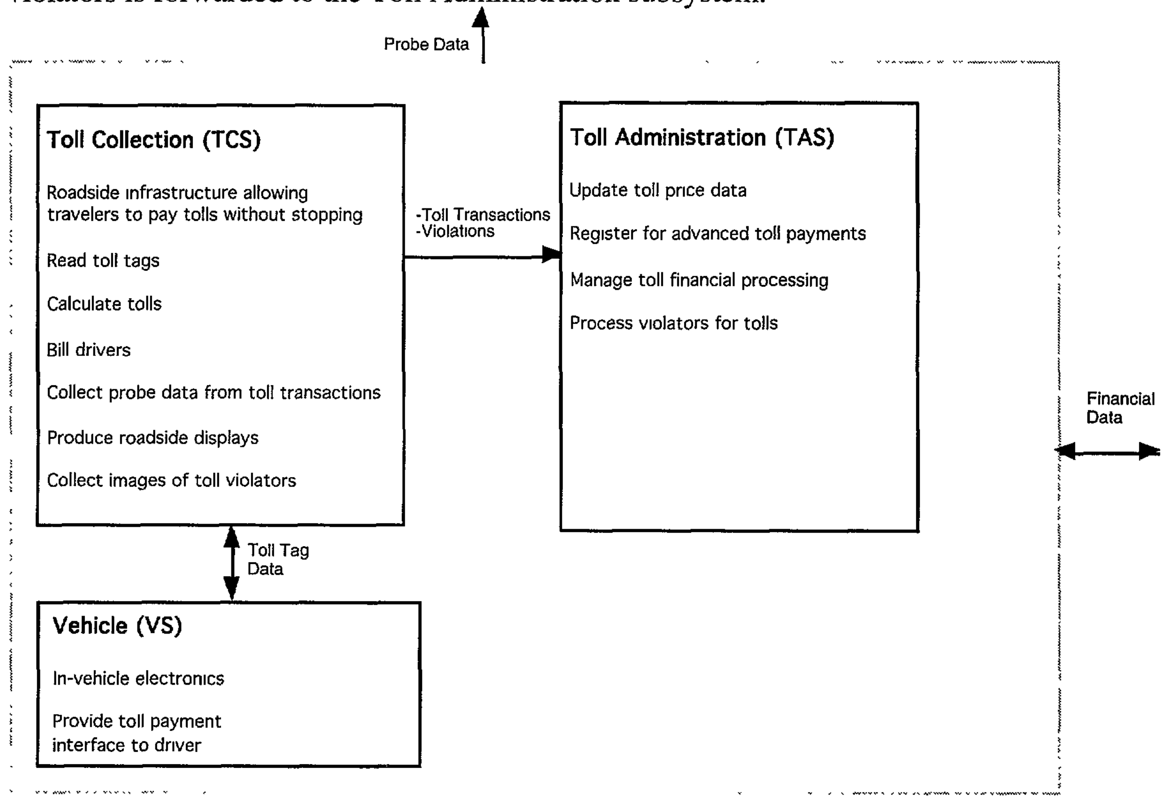
**User, Ride, and Fare Data:** user's tag identification and category, transit route and time, fare rates

**Payment Requests:** request to pay for future trip (includes origin, destination., date and time)

**Transit Vehicle Location:** transit vehicle's identification and location

## Electronic Toll Collection

Three architecture subsystems make up the Electronic Toll Collection component. The Toll Collection subsystem (TCS) is the roadside infrastructure, such as tag readers, that is needed for toll collection. It communicates with the in-vehicle electronics in the Vehicle subsystem (VS). Although the primary purpose is toll collection, an auxiliary benefit is the use of the Toll Collection subsystem to collect probe data for the Traffic Signal Control/Freeway Management components. In fact, additional toll tag readers can be employed at locations where no toll collection takes place. Deployed strictly for the purpose of obtaining probe data, they measure the time a vehicle takes to travel between two readers. Probe data are used by the ITI Traffic Signal Control/Freeway Management components to calculate link journey times for use in adaptive traffic control techniques. and by the Incident Management component to help detect flow stoppages which may indicate the presence of an incident. Toll transactions and information, including video, on violators is forwarded to the Toll Administration subsystem.




**Electronic Toll Collection Data Flows:**

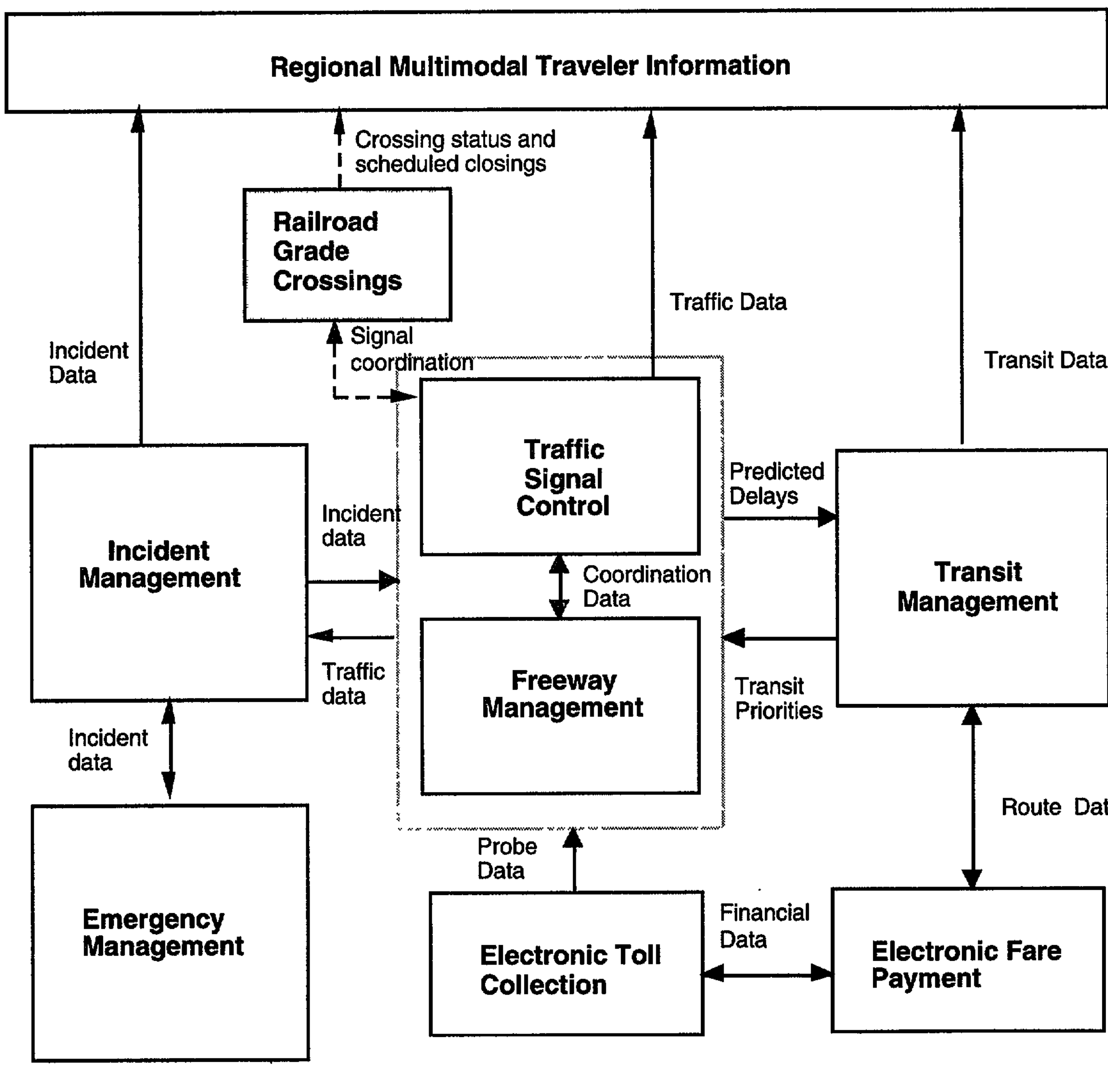
**Toll Transactions:** data on current and advance toll payments(incl. credit card number and toll costs)

**Violations:** digitized image of a vehicle trying to violate the toll collection process or a vehicle currently entering a toll plaza whose tag cannot be correctly read

**Toll Tag Data:** data needed to make toll payments, such as credit identification, value of credit stored on the tag, and road segments for which the toll applies

## Railroad Grade Crossings

At this time, the architecture does not include provisions for Railroad Grade Crossings. Therefore, if you read the architecture documentation looking for specifics on this ITI component, you won't find it. As you recall from Section 3, the architecture was developed to meet the requirements of the 29 user services. Railroad Grade Crossings were not part of the original list. However, now that a requirement has been defined, the architecture will be updated to incorporate it. This is an example of how, as we learn more about ITS and new requirements are identified or old ones are updated, the architecture will be updated to reflect the needed interfaces to the new requirement. At this point, specifics have not been developed as to how this component will interface to the other ITI components. However, best estimates are that the primary interfaces will be with Traffic Signal Control and Regional Multimodal Traveler Information.

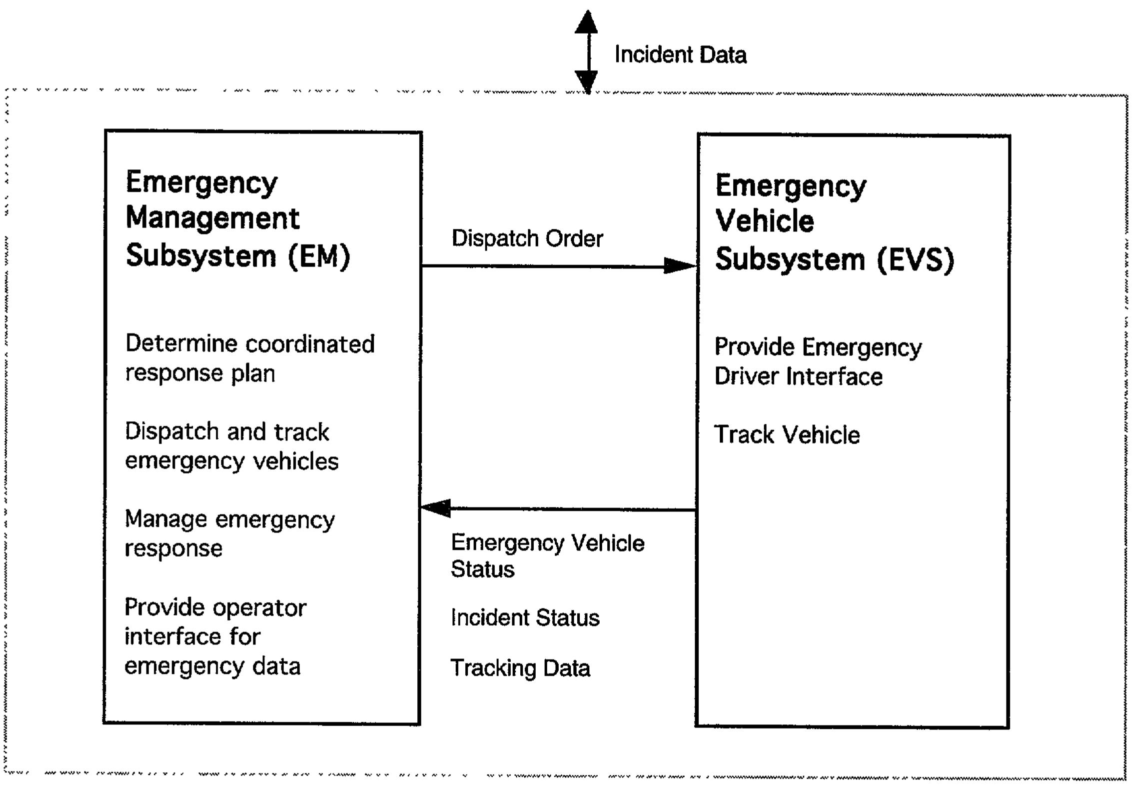



**Railroad Grade Crossing Data Flows:**

Since this ITI component is not yet defined within the architecture, the data flows within the architecture have not been defined.

## Emergency Management Services

Emergency Management functions are assigned to the Emergency Management (EM) subsystem and the Emergency Vehicle Subsystem (EVS). The Emergency Management component is closely interfaced to the Incident Management component. It dispatches and tracks the appropriate vehicles. Updates of the incident data are passed back to the Incident Management component as the response proceeds. Emergency Management also provides the operator interface for emergency data. The Emergency Management subsystem sends messages to the Emergency Vehicle Subsystem to dispatch a vehicle and receives status updates from the vehicle. Tracking data enables the vehicle to gain priority at traffic intersections and freeway ramps.




**Emergency Management Data Flows**

**Dispatch Order:** order for driver to proceed to incident, vehicle identification, incident type, incident location

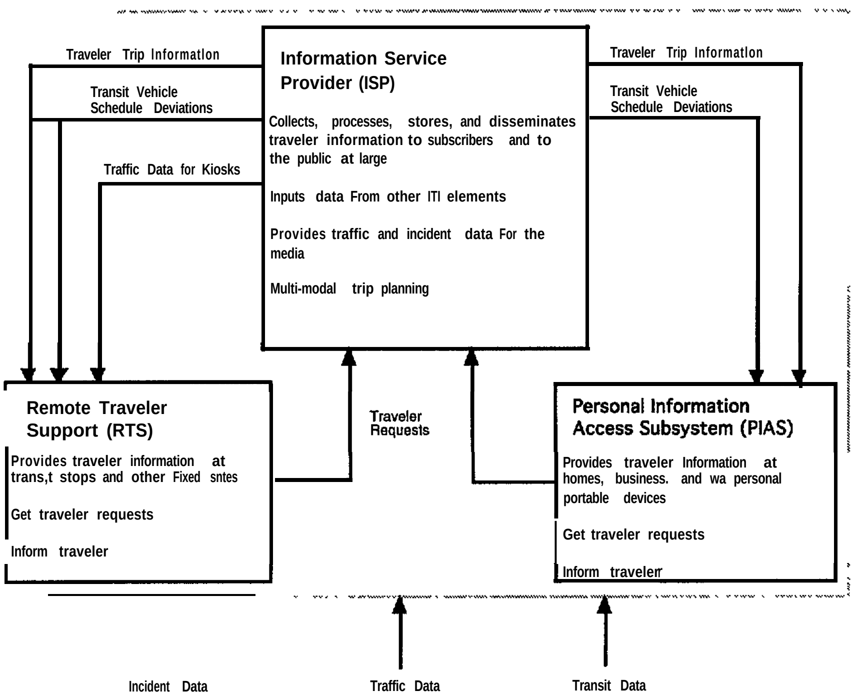
**Emergency Vehicle Status:** vehicle availability, current activity (en-route to/at/returning from an emergency), vehicle identification, incident identification number

**Incident Status:** length of time to clear incident, length of time at worksite

**Tracking Data:** vehicle identification and current location

## Regional Multimodal Traveler Information

Three architecture subsystems are used to provide Regional Multimodal Traveler Information. Incident, traffic, and transit data from the other IT1 components are input, processed, and stored by the Information Service Provider (ISP). The other two subsystems, Remote Traveler Support (RTS) and the Personal Information Access Subsystem (PIAS), essentially duplicate each other's functionality. They request information from the ISP and provide it to the traveler. However, the electronic media used for dissemination of the information differs between them. RTS disseminates the information at fixed sites, such as at signs at transit stops. RTS also provides kiosks at shopping malls and other public locations. The PIAS, on the other hand, disseminates traveler information in the home or place of business using personal portable devices and other electronic media.




**Regional Multimodal Traveler Information Data Flows**

**Traveler Trip Information:** includes information on traffic conditions, transit routes, and schedules

**Transit Vehicle Schedule Deviations:** deviations from published routes and schedules

**Traffic Data for Kiosks:** current and predicted traffic conditions on the road network

**Traveler Requests:** traveler trip requests that include traveler identification, origin/destination, and time of trip; requests for current information on traffic conditions and incidents

## 5. Common Questions Raised by Implementors

Now that you've read all of this, you probably have questions. In developing the architecture and in preparing this handbook, we spent a great deal of time talking to implementors. From these interactions, we've identified a list of "frequently asked questions" and have prepared answers for them.

**Q: The architecture doesn't specify standards to be used in deploying the IT1 but indicates that they should be used once developed. What do I do to ensure that my current investments are not negated by future technology developments? What do I do while I'm waiting for these standards to be developed?**

**A:** The architecture addresses the systems that make up IT1 and discusses data that must be shared between systems. It also identifies some ongoing standards activities that may support deployment based on the architecture. The architecture should be used in designing a system or evaluating a potential deployment to make sure that all capabilities and dataflows defined by the architecture for that subsystem are supported and that key interfaces are developed. By doing this, you can realize immediate ITS benefits, while maximizing your ability to adopt future standards when performing upgrades.

**Q: I am building a Traffic Management Center now and have plans to collect surveillance data. Someday, I may want to be able to distribute this information to the public (e.g., link travel times) via and ISP. What can I do now so that I don't preclude that option in the future?**

**A:** The architecture addresses the issue of providing this type of data to ISPs. Review the architecture regarding the contents of messages that will be needed to support this function. In designing your system, make sure that you have collected, or at least considered, all of the data which the architecture considers necessary for this interface. When you develop your custom interface between your TMC and the ISP , isolate it from the rest of your system so that, once a standard has been developed, you can quickly redesign that interface without having to change the rest of your system. This is an excellent approach to "buying smart" and is expected to have significant economic benefits in the future.

**Q: I'm sold on the concept of the ITI, but can I afford it?**

The components of the IT1 are not new budget items to State and local jurisdictions. Most State and many metropolitan areas are already using Federal-aid funds to purchase or upgrade IT1 systems, including traffic signals, freeway management, transit management, incident management, electronic fare payment and toll collection, traveler information centers, railway-highway grade crossings, and emergency management. Many of these systems are already in place and were purchased with Federal-aid funds.

As you upgrade, repair, or replace these existing systems, you need to plan ahead for system integration, and "buy smart." In the future, State and local jurisdictions need to purchase component systems that are able to share data with other transportation systems and with neighboring jurisdictions, so that the public can experience the benefits of integrated metropolitan transportation management.

Our emphasis on "buying smart" is directed at encouraging implementors to be aware of what the future requirements may be, and to know what "sister agencies" in the same and surrounding jurisdictions are planning. In this manner, for example, agencies which need to communicate with one another during a traffic incident (as with freeway management and emergency response entities) would get together to establish common functional requirements and specifications for radio and data links so that “real-time” coordination can take place. Financially, it may be feasible to combine purchase needs into a single, larger procurement which would benefit all participating agencies due to economies of scale. In addition to these types of financial benefits, we also are working to encourage agencies to continue efforts to partner with private sector firms, especially in the area of traveler information dissemination. Most aspects of this type of integration and innovative financing are eligible under current Federal-aid funding categories, and we encourage States and other entities to work with appropriate U.S. DOT offices regarding these opportunities.

**Q: How should my future designs include both existing equipment and conform to the architecture? What should I do to ensure that future upgrades of my equipment conform to the architecture?**

**A:** As you plan new features and upgrades to your systems and subsystems, you should review the design of these new features to make sure the interfaces utilize the architecture or, eventually, the standards recommended by the architecture. Over time, proprietary interfaces will phase out if no one is buying them and will be replaced with open interfaces that can readily be interfaced to other subsystems. This will not all happen overnight. In some cases, protocol converters may be needed to interface existing equipment to newer equipment until such time as the existing equipment needs to be replaced. At that time, it should be replaced by a system supporting open interfaces. Standards can provide a messaging format to minimize interface cost and complexity.

**Q: I live in a rural area of the country. However, this handbook seems to focus primarily on urban transportation systems. What should I be doing?**

**A:** The IT1 includes support for rural implementations and the architecture addresses rural services. This handbook has been limited in scope to focus on urban applications. Future guidance will be provided that helps implementors interpret the architecture from a rural perspective.

**Q: Where does the architecture allocate “intelligence” in the system? Is it centralized or distributed?**

**A:** The architecture is flexible enough to support both distributed intelligence and centralized systems. For route guidance applications, it is assumed that more system intelligence will reside within the vehicle in the near-term and that, over time, more centralized systems may evolve. For traffic management, the architecture supports both types of systems, although coordination functions are generally centralized in nature.

**Q: I am concerned that by providing data to private sector Information Service Providers (ISP) and letting them package and disseminate it to travelers, I may lose control over my transportation system. What can I do to prevent that? (e.g., suppose an ISP routes all of my freeway traffic through local streets to avoid a backup?)**

**A:** The architecture specifies the types of data that should be shared between subsystems. Restrictions as to how that data is used will have to be determined on a regional basis. If a local DOT wants to place limitations on where vehicles are routed during a backup, that DOT will have to reach an agreement with the ISP receiving the data as to how it can be used and will need to determine an approach for enforcing the agreement.

**Q: Who will own and operate ITS/ITI?**

**A:** Various deployment options are possible with the ITI/ITS. The public sector will undoubtedly retain ownership of some portions, some portions may be provided by the private sector, and some may entail public/private partnerships. Public/private partnerships can take many forms, including contracting out of maintenance and/or operations, privatizing services, franchising, or consortia. The architecture itself is independent of these various options and any combination of the three may be possible. And, there is expected to be some regional variation in how deployment occurs. The architecture only defines the subsystems and dataflows between subsystems and does not specify who owns or operates the various components. Ownership of the different components and responsibility for operation will be determined on a regional basis.

**Q: As technologies and applications evolve, it is certain that changes will be required to the architecture. Are there plans to maintain and evolve the architecture? As an implementor, how will I be made aware of these changes?**

**A:** Plans are underway for maintaining the architecture into the future once the initial architecture development is complete. Items that may cause the architecture to change would be new user services, modifications to existing user services, or corrections required as more implementors begin using the architecture. A process has yet to be determined for distributing future changes but it is our intention to make such information widely available.

**Q: As I deploy the IT1 components, should I install my own communication systems or should I lease commercially available communication links?**

**A:** This decision will vary on a regional basis and even within a region and will depend upon a number of factors including:

- Requirements analysis - What functions will be supported? How much capacity do you need? What coordination is appropriate with adjoining jurisdictions?
- Technical design tradeoffs - are commercial links available to support an installation? Do they offer sufficient capacity? Are they accessible where you need them?
- Cost tradeoffs - can commercial communications links provide the same services at lower cost? Should you consider a public-private partnership? You should be sure to include total life-cycle costs and benefits in the analysis
- State/local regulatory environment - What effect may State/local requirements have on communications procurement? You should closely examine potential opportunities in your area which may provide access to communications infrastructure.
- Existing equipment - what infrastructure have you already installed? How can you best augment your current capabilities?

**Q: Does the architecture depend solely upon cellular telephone technology and Cellular Digital Packet Data (CDPD) for ITS data transmission?**

**A: No.** The architecture is an open architecture and can support a wide range of deployment options. Since part of the National ITS Architecture Development Program included the requirement to evaluate the architecture, it was necessary to develop a design based on the architecture (you can't evaluate an architecture.) For this evaluation, CDPD was chosen as the two-way wide area wireless communication technology. Other media may be used for both two-way communication and one-way broadcast of information.

**Q: Is it true that the architecture excludes beacons for communication between the roadside and the vehicle?**

**A: No.** The architecture makes use of beacons where they are appropriate such as for toll collection and commercial vehicle operations. The architecture also supports the optional use of beacons for some other applications, such as vehicle probe reports, as is being done in Houston. However, a general purpose beacon infrastructure to support other ITS applications such as route guidance and navigation is not cost-effective and is neither recommended nor supported by the architecture.

**Q: The architecture seems to be fairly general and covers everything. What would constitute non-conformance with the architecture? What should I do to begin to utilize the architecture?**

**A:** The architecture doesn't make technology decisions for you. It's not supposed to. The architecture provides a framework for thinking about the problem. It looks at the problem on a functional basis and tries to optimize the aggregation of functions. The key is to ensure that the various systems and components can exchange the information specified in the architecture. The architecture identifies ways to take advantage of synergies (see Section 3). As you get into regional deployment, you will need to worry about regional concerns (How can I best interface with the jurisdiction next door?) and design tradeoffs (What's the best, most affordable way to implement this capability?) Your regional architecture will address how you will integrate your systems. If you haven't gone through the thought process shown in the architecture documents, your system may be more of an unmanageable kludge than an upgradeable, maintainable system. (Much like an old coal furnace...it interfaces to your heating ducts and warms the house, but there are much more efficient ways to do the job.) Given enough money and enough custom interfaces, any one system can be made to communicate with another system.

Utilizing the architecture helps you minimize the time and costs to upgrade, integrate, and evolve. Plus, architecture is an evolving process. As standards are developed, they will be tailored to the subsystems and interfaces defined in the architecture. Utilization of adopted standards will be the ultimate measure of the success of the architecture. If you follow the architecture today, then several years from now when there are clear standards and guidelines, you will likely be close to being able to take advantage of the benefits of architecturally compatible equipment in future procurements. If you didn't consider the architecture in your design and didn't follow its evolution, then your system could be a one-of-a-kind, standalone system, which can be quite difficult and expensive to upgrade or expand.

The architecture provides a framework that both implementors and vendors can follow as a guide for designing and deploying systems. Following the architecture ensures that you will have a competitive migration path as you upgrade your systems and add more functionality. By not following the architecture, you risk locking yourself into a single vendor system with the inherent costs, limitations of future growth, and risk of no future support.

**Q: I thought that CVO is a major part of ITS. Why is there limited discussion of CVO requirements in this handbook?**

**A:** The IT1 includes support for CVO applications and the architecture addresses CVO in detail. This handbook has been limited in scope to focus on urban applications. Future guidance will be provided that helps implementors interpret the architecture from a CVO perspective.

## Appendix: How to Find Information in the Architecture Documentation

The architecture is documented in a number of volumes totaling approximately 3600 pages. The primary breakdown of this documentation set is:

**Architecture definition:** This includes all of the technical detail on functions and subsystems, what they are, and what information is exchanged. These are the blueprints.

- -Mission Definition
- -Vision
- -Theory of Operations
- -Logical Architecture
- -Physical Architecture
- -Traceability Matrix
- -Communications Document

**Deployment Options:** These documents discuss various options that the designers of the architecture envisioned for deploying ITS and ITI. These documents begin to discuss design issues but don't tell you exactly what to buy.

- -Implementation Strategy
- -Standards Requirements
- -Standards Development Plan

**Architecture Evaluation:** This set of documents summarize the analysis conducted by the architecture designers to show that the architecture would actually work. Remember, you can't evaluate an architecture...you have to evaluate an *implementation* of the architecture. These documents discuss how various "evaluatory designs" were evaluated. While none of these sample analyses will exactly match your deployment requirements, they can be used to help you structure your own analysis and provide you with a checklist so you don't miss anything.

- -Performance and Benefits Study
- -Cost Analysis
- -Risk Analysis
- -Evaluation Summary
- -Evaluatory Design

A brief synopsis of the content of each document follows:

**Mission Definition** - ties the architecture to the national program plan and addresses goals, objectives, user service requirements, and expected benefits.

**Vision** - magazine style view of what ITS will look like in the future.

**Theory of Operations** - a technical narrative and walk-through of how the architecture supports ITS in operation.

**Logical Architecture** - a functional view of what is needed to implement ITS. This is a large document and defines all of the processes and data flows between processes. You would probably reference this only to look at specific functions. This document addresses "what" functions need to be done.

**Physical Architecture** - collects related functions into subsystems and defines the interfaces between subsystems. This document addresses "how" subsystems should be connected to make ITS work.

**Traceability Matrix** - Provides a detailed mapping between the logical and physical architecture. Used only by those doing detailed analysis.

**Communications Document** - a thorough analysis of the communication requirements of the architecture and ITS including discussion of options for implementation of the various communications links.

**Implementation Strategy** - discusses examples of how the architecture can be deployed.

**Standards Requirements** - detailed information regarding standards packages that need to be developed to implement the architecture.

**Standards Development Plan** - discusses the steps necessary to produce interface standards. The audience for this document is primarily the Standards Development Organizations and system designers.

**Performance and Benefits Study** - discusses the benefits of having and deploying to an architecture.

**Cost Analysis** - provides unit and system costs for deploying ITS based upon the architecture.

**Risk Analysis** - assesses risks threatening architecture deployment and presents mitigation strategies for those risks.

**Evaluation Summary** - a summary of the various evaluations conducted during development of the architecture.

**Evaluatory Design** - provides a unifying set of assumptions as a basis for the evaluations.

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