ITS Implementation Strategy

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EXECUTIVE SUMMARY

Nationwide implementation of Intelligent Transportation System (ITS) services will result from a multitude of individual deployment decisions by public agencies and the private sector. The National ITS Architecture creates the opportunity for interoperability across these diverse ITS deployments while preserving flexibility and choice for the many implementors.

The architecture is implemented to achieve these benefits in three principal ways: (1) adaptation or development of consensus standards for transportation products based on architecture requirements, (2) development of regional architectures which interpret the national architecture and tailor it to support integrated regional ITS solutions, and (3) incremental deployment of architecture compatible systems.

The Implementation Strategy defines a series of steps that encourage efficient deployment of architecture compatible systems. These include:

- Identification of basic building blocks that apply to most ITS deployments,
- Focus on near-term problems and the early deployments best suited to addressing those problems through the Intelligent Transportation Infrastructure initiative,
- Further encourage private sector participation in ITS deployment,
- Parallel advancements in the number of ITS services offered and the degree of system integration over time.

Each of these steps are used to inform state and regional guidance as well as specific US DOT recommendations. This summary will highlight the main findings that are more fully developed and supported in the body of the Implementation Strategy document.

Identify ITS Building Blocks. The architecture must support all user services, be scaleable to suit the largest metropolitan areas as well as remote rural regions, and be technology independent so that current and future technologies are accommodated. This flexibility enables each implementor to use existing assets and provides a variety of evolutionary paths for maturing ITS capabilities based on individual priorities. Unfortunately, this flexibility also makes it difficult to understand precisely what pieces of the architecture are applicable and how they can best be applied in solving a particular communities current transportation problems.

To provide visibility into the service options that will be considered by ITS implementors, a set of *market packages* have been defined. The market packages are tailored to fit - separately or in combination - real world transportation problems and needs. The strategy is structured around more than fifty of these packages that illustrate the range of incremental deployment options that may apply to different scenarios and time frames. The market packages address specific services that might be required by traffic managers, transit operators, travelers, and other ITS stakeholders.

Market Packages

Traffic Management

- Network Surveillance
- Probe Surveillance
- Surface Street Control
- Freeway Control
- HOV and Reversible Lane Management
- Traffic Information Dissemination
- Regional Traffic Control
- Incident Management System
- Traffic Network Performance Evaluation
- Dynamic Toll/Parking Fee Management
- Emissions and Environmental Hazards Sensing
- Virtual TMC and Smart Probe
- Standard Railroad Grade Crossing
- Advanced Railroad Grade Crossing
- Railroad Operations Coordination

Emergency Management

- Emergency Response
- Emergency Routing
- Mayday Support

Traveler Information

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

Commercial Vehicles

- Fleet Administration
- Freight Administration
- Electronic Clearance
- Electronic Clearance Enrollment
- International Border Electronic Clearance
- Weigh-In-Motion
- Roadside CVO Safety
- On-board CVO Safety
- CVO Fleet Maintenance
- HAZMAT Management

Transit Management

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

Advanced Vehicles

- Vehicle Safety Monitoring
- Driver Safety Monitoring
- Longitudinal Safety Warning
- Lateral Safety Warning
- Intersection Safety Warning
- Pre-Crash Restraint Deployment
- Driver Visibility Improvement
- Advanced Vehicle Longitudinal Control
- Advanced Vehicle Lateral Control
- Intersection Collision Avoidance
- Automated Highway System

ITS Planning

- ITS Planning

The market packages are tightly coupled with the architecture definition and represent the “building blocks” that can be deployed over time to efficiently achieve high-end ITS services. Several different market packages are defined for each major application area which provides a palette of services at varying cost. Market packages are also identified to segregate services which are likely to encounter technical or non-technical challenges from lower risk services. For example, driver warning and vehicle control systems are defined as separate market packages due to the increased technical and non-technical risk associated with systems which dilute the driver’s direct control of the vehicle. This approach yields market packages that may be deployed early with low risk. Many of the market packages are also incremental so that more advanced packages can be efficiently implemented based on earlier deployment of more basic packages.

Recommend Early Deployments. The market packages are inter-related and are also influenced by the availability of basic supporting infrastructure, the evolution of technology, the emergence of industry standards, the institutional context of implementation, and market demand. Different market packages will be impacted to varying degrees by each of these factors.

It is difficult to predict when many of these factors will be resolved. Instead, the strategy suggests early deployments that are not dependent on technology advances or institutional change and leave room for a competitive environment on which to advance transportation technologies. *Early Market Packages* are the subset of market packages that appear to be early winners due to a promising combination of low risk implementation characteristics, developing public and private markets, and tangible system or user benefits. Market packages that best satisfy the above criteria include: Surface Street Control, Freeway Control, Standard Speed Railroad Grade Crossing, Dynamic Toll Management, Transit Vehicle Tracking, Transit Operations, Mayday Support, Autonomous Route Guidance, ITS Planning and Electronic Clearance.

The nine elements identified by the Intelligent Transportation Infrastructure initiative further prioritizes those early market packages that are oriented towards public infrastructure support for major metropolitan areas. This provides additional near-term focus for the strategy. Early deployments have and will continue to occur in larger metropolitan areas given their need, greater availability of resources, and the existing infrastructure to build upon.

Encourage Private Sector Participation. The Intelligent Transportation Infrastructure initiative represents a tangible commitment to deploy key public infrastructure that should promote further deployments of ITS services. The implementation strategy described in this document proposes a shift in funding from financially strapped public agencies to private users. This shift is accomplished through emphasis on individual user fees for services and other incentives that enhance the potential for profitability and encourage capital investments by private industry. The relative emphasis within the architecture on vehicle based systems and the separation of transportation management and transportation information services are examples of choices which preserve and enhance the opportunity for private sector participation. It is forecast that several key functions will remain a public responsibility, including traffic management and emergency management services where direct user fee based operation is impractical.

Enable Service Integration and Extend Interoperability. The strategy begins with what we have now: “Islands” of basic ITS capability that are deployed in response to local needs. Adoption of existing standards and development of new ITS standards encourages service expansion and eventual linking of these ITS islands. The implementation strategy considers the minimum level of standardization required to achieve interoperability while preserving existing investments and the potential for innovation. This balanced view emphasizes the interfaces to vehicles and other mobile elements for standardization and leaves the other regional and sub-regional interfaces to evolve towards open standards based more on local needs than top-down national priorities. The associated Standards Development Plan and Standards Requirements deliverables provide the guidance from the ITS architecture to the Standards Development Organizations (SDOs).

The National Architecture provides a general framework that must be adapted and elaborated for use in supporting an interoperable regional transportation system design. It is recommended that a regional architecture is developed as a major output of this process which adapts the National Architecture to reflect major service, technology, and interface choices which are most appropriate for the implementing region. A series of steps are offered to assist the local implementor in applying the National Architecture in a regional setting.

Progressive Implementation of More Advanced Services. The strategy provides a vision of how the ITS services could be provided over time for a representative set of scenarios. These forecasts document efficient deployment sequences that reflect a projected natural evolution of ITS service provision through market development and appropriate public sector decision-making. Geographic expansion will be paralleled by technology growth resulting in new capabilities, new products, and new features. For example, early deployment of basic toll collection capabilities enables future, efficient deployment of vehicle probe data collection, which in turn enhances advanced traveler information market packages and more advanced, area-wide traffic control strategies.

Integration into State and Local Planning and Programming. The strategy emphasizes the integration of ITS architecture deployment with state and metropolitan transportation planning, programming, and maintenance decisions. Guidance is provided for: ascertaining appropriate market packages; establishing a regional ITS architecture; devising strategic ITS plans that conform with the regional architecture; identifying key interfaces and standards to be considered in deployment; and evaluating operational systems. The implementation strategy considers the regional ITS deployment process from the vantage of new systems as well as existing systems.

Recommended DOT Strategic Actions. The strategy culminates in a series of top-level recommendations for strategic actions that are intended to facilitate ITS deployments. These actions should lower identified deployment barriers and otherwise enhance the prospects for beneficial adoption of the National ITS Architecture through efficient ITS implementations.

> ***Facilitate National Interoperability.*** The strategy recommendations complement the current US DOT "ITS Standards Development" activity which is promoting ITS standards development through five contracts with the AASHTO, IEEE, ITE, ASTM, and SAE Standards Development Organizations. Education programs and other forms of outreach are recommended to ensure active participation in, and beneficial adoption of, the standards that are developed.
>
> Depending on interface-specific interoperability issues, standards adoption may be voluntary, encouraged through conditional funding, or regulated at the regional, state, or national level. Preliminary recommendations for the appropriate public sector role in encouraging standards adoption concentrate on those interfaces that are most critical to national interoperability. General approaches towards accommodating legacy systems while encouraging standards adoption in newer systems are addressed. The best solution for supporting legacy systems is dependent on the situation, but

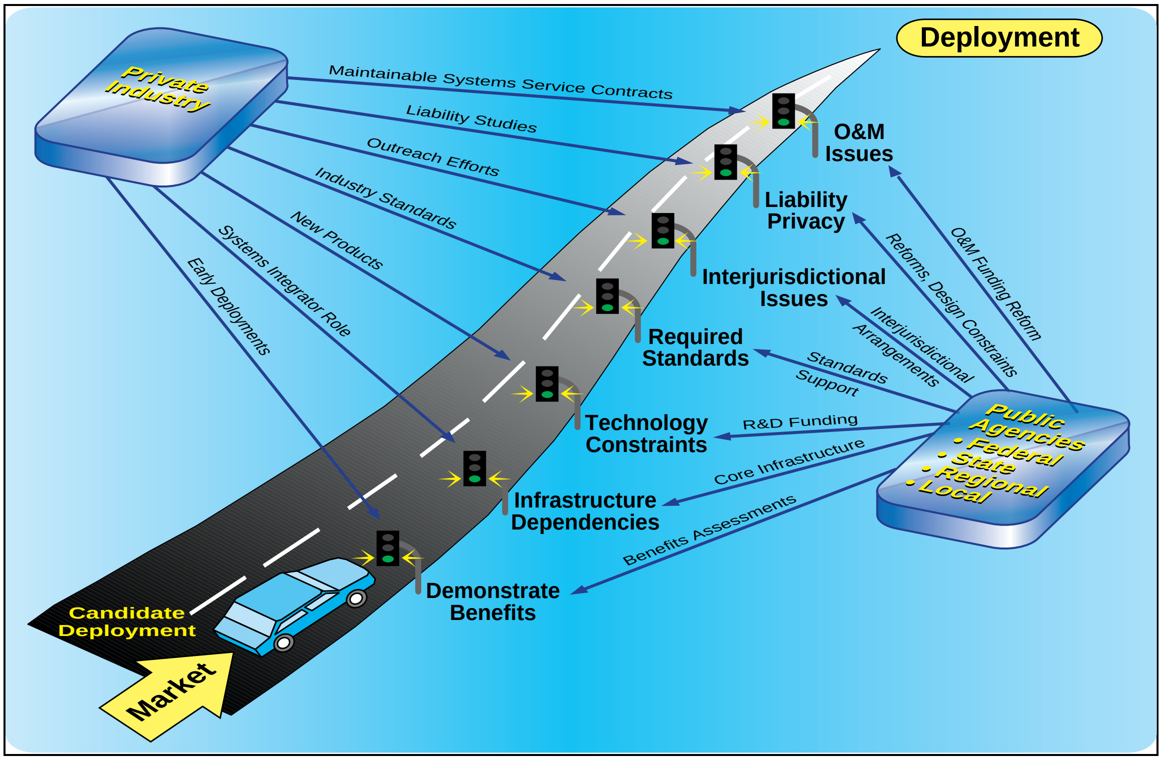
typically involves conversion to newer, interoperable systems over time in the course of normal system maintenance and upgrade. The range of potential conformance testing and certification programs are also briefly described. Finally, a potential approach to maintaining the national architecture products over time is suggested which maintains only the subset of the architecture products that directly support the evolving standards and implementation guidance efforts.

Policy and Guidance. First, the local implementor must be equipped with sufficient information to make appropriate ITS architecture choices. Education and training programs which enlist regional field representatives as local champions and continuance of the on-going federal efforts to consolidate and publish ITS benefits are positive steps to this end. Improved evaluations must be performed to augment currently available information. Such evaluations should be oriented towards generating the kinds of benefits information that will be relevant and useful to implementors. For instance, benefits information that is developed should be useful in scoring potential ITS projects against the 15 planning factors identified in ISTEA (e.g., Overall social, economic, energy, and environmental effects of transportation decisions, congestion relief and prevention, consistency of planning with energy conservation measures). Each of these programs must be supported by preparation of handbook level guidance and update of existing transportation manuals, handbooks, and publications over time.

Policy recommendations augment the guidance by mitigating recognized barriers. Approaches to facilitating multi-jurisdictional agreements, applying the ITS Privacy Principles, continuing proactive procurement reform, enabling direct recovery of user fees for services, and managing public sector liability are recommended.

Strategic Investment. Funding recommendations are made for early deployments which verify and refine integration strategies (e.g., encourage regionally integrated transportation management systems that lend credence to and/or refine the architecture framework that has been established), field operational tests which resolve major implementation choices (e.g., the role of probes versus roadside surveillance), and research and development activities that develop the tools (e.g., Improved ITS Benefits/Impact Models) and technologies (e.g., advanced vehicle sensor and control technologies) that support ITS implementations.

Achieving Efficient ITS Deployment Through Public and Private Sector Initiatives



1. Introduction

1.1 Purpose

The Implementation Strategy (IS) is one of a series of deliverables documenting the National Intelligent Transportation System (ITS) Architecture developed under contract to the US DOT. The Implementation Strategy describes the architecture to potential implementors, clarifies the relationship between architecture and implementation, and recommends policies and actions that will encourage cost-effective nation-wide implementation of ITS. Through these definitions and recommendations, the Implementation Strategy provides a general vision of how an efficient deployment of systems compatible with the national architecture can take place over time. It explicitly recognizes the extreme variability in deployment that will occur in different areas of the nation at different times and provides an overall strategy that spans, and supports, these diverse deployments.

What is the Implementation Strategy trying to do?

- Describe the National Architecture and its relationship to ITS implementations to potential implementors.
- Identify potential issues that could impede the deployment of systems within the architectural framework
- Recommend policies and actions that will encourage cost-effective implementations that are compatible with the National Architecture
- Examine deployment alternatives that offer balanced approaches for public, commercial, and private investment
- Provide snapshots at various times in the future illustrating the potential time phased deployment of ITS services.

What is the Implementation Strategy not attempting to do?

- Prescribe a specific deployment sequence or implementation. Each deployment will be adapted to prevailing local conditions and requirements and cannot be nationally prescribed.
- Dictate ownership, financial, and operational responsibilities. The identification of public sector and private sector roles will be dependent on the needs of each community.

The merit of the National Architecture will only be realized through deployment of architecture-compatible systems. As presented in Figure 1.1-1, the Implementation Strategy plays a key role in bridging from the National Architecture Definition (documented in separate Logical Architecture and Physical Architecture deliverables) to real-world ITS deployments. It is intended to instruct transportation practitioners in the appropriate application of the architecture products in ITS implementations. It is anticipated that this Implementation Strategy will serve as a source for and mature into more comprehensive Implementation Guidance. Companion Standards Development Plan and Standards Requirements Documents build on the basic architecture definition in a similar fashion but are products oriented towards the Standards Development Organizations and development of standards which follow from the architecture definition.

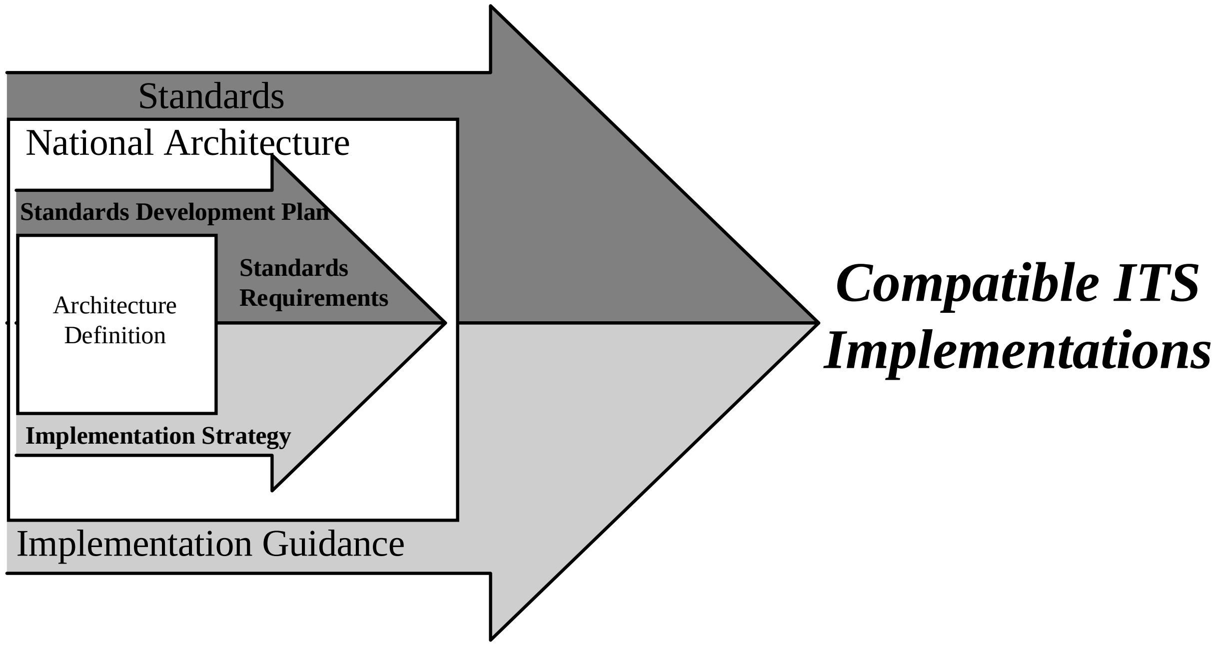


Figure 1.1-1: The Implementation Strategy in Context

1.2 Guiding Principles

Wide spread implementation of ITS services will result from a multitude of individual deployment decisions by public agencies and the private sector. The National Architecture preserves choice for each of these implementors by limiting its scope to include only those interfaces and functional descriptions that address key system interoperability issues. This conservative scope allows each implementor to make maximum use of existing assets and provides a variety of evolutionary paths for maturing ITS capabilities based on individual priorities.

The National Architecture was developed by a diverse group of private companies, public agencies, and technical specialists which represent a microcosm of the range of stakeholders who will ultimately influence the scope and character of future ITS deployments. The architecture has benefited from participation by public agencies at the national, state, regional, and local levels. The issues which resonate from these organizations include preservation of local autonomy, effective utilization of what has already been built or is currently under construction, and flexibility to expand as local authorities deem appropriate. Institutions are very willing to cooperate as long as their interests are preserved.

These issues were echoed by private sector members of the team with the additional recommendation that utilizing existing infrastructure enables rapid early deployment, reduces risk through utilization of known technologies and organizations, and allows more reliable cost estimation. Leveraging the existing and emerging national communications infrastructure minimizes capital investment and new communication spectrum requirements. The nature of the formative ITS market and risk factors which may discourage active private sector investment and participation in pursuing these markets were also identified by private sector participants and accommodated in this strategy.

Reaching beyond the development team in a series of regional forums, focus groups, and personal interviews with various user groups, a significant requirement to address **all** of the stakeholder needs becomes evident. Failing to recognize individual special needs introduces a dis-interested party; one who may not support integration with the other ITS providers and may not accept ITS recommendations. Technical specialists have provided the balancing guidance to address all of these stakeholders' needs including transit agencies, funding institutions, and other governmental bodies.

These considerations resulted in an Implementation Strategy which is based on several key principles:

Accommodate Varied, Incremental Deployment of ITS
- This "strategy" is not a prescription for every community, or even one community. It attempts to identify the key ingredients for successful ITS deployment. The recipe for a particular community must be based on identified needs and available resources.
- The strategy supports the critical needs of public organizations to maintain and improve existing systems. Initial ITS implementations will build on these systems.
- The strategy suggests early deployment of key enabling infrastructure that is aimed at the most critical problems of the particular locale. Early implementations enhance management of the transportation network and form a basis for many of the value-added information services associated with ITS.
- Staged implementation begins with these "islands" of basic ITS capability that are deployed in response to local needs. Increased travel demand, greater traveler expectations, and evolving needs encourages service expansion and eventual linking of these ITS islands. Geographic expansion will be paralleled by technology growth resulting in new capabilities, new products, and new features.

Expedite Development of Key Standards
- ITS standards provide a unifying framework that will enhance the interoperability of these diverse, locally-responsive ITS implementations. The strategy recommends the minimum level of standardization required to achieve interoperability while preserving existing investments and the potential for innovation.

Encourage Exploitation of Market Forces
- Market forces are relied upon, wherever possible, to promote implementation of ITS services. Such markets are expected to introduce many of the early products including electronic toll collection, route guidance, and commercial vehicle operations.
- As implementation issues are addressed, market demand will spur deployment of an increasing number of ITS services as a natural progression. The strategy intervenes only where necessary to stimulate and ensure the achievement of system inter-relationships, system goals (e.g. safety), and deployment of key technical dependencies.

- The strategy recognizes the benefit to the public that can be achieved when multiple entities, public and private, enter into partnerships to provide service. Private sector participation is promoted through emphasis on individual user fees for ITS services and other incentives that enhance the potential for profitability and encourage capital investments by private industry.

1.3 Document Structure and Intended Audience

The Implementation Strategy document is intended to serve the transportation professional who is involved in ITS implementation and wants to understand the implications of the National Architecture on such implementations. This Implementation Strategy (and the remaining National Architecture documents) will be of particular interest to those that are developing, or supporting the development of, regional ITS systems. This group includes system integrators, state and local implementors who are progressing towards integrated ITS implementations, and US DOT.

The Implementation Strategy builds from the architecture definition to specific recommendations for the ITS implementor over the course of the document. The contents of each of the document sections and the supporting appendices are summarized in the following paragraphs.

Sections 2 and 3 describe the architecture and the institutional context in which ITS implementations will occur. The material in these sections is the basis for the guidance and strategic recommendations that are presented in later sections. Sections 2 and 3 provide basic background information and overall concepts that should be germane to the entire audience for the document.

> *Section 2. What are the Potential Implementations?* This section defines the National Architecture and describes its relationship to ITS implementation and the Intelligent Transportation Infrastructure (ITI). Major technology and standards requirements that are associated with the range of potential ITS implementations are identified. Important early deployments and synergies that enable efficient incremental implementation of more advanced services are also defined.
>
> *Section 3. Implementor Roles and Deployment Implications.* ITS implementation ultimately relies on a diverse set of public and private sector implementors and implementation activities. Each of these implementors, their interactions, and their roles are differentiated and discussed within the context of the Institutional Layer of the National Architecture. The extent to which the formative market for ITS services can be relied on as a principal driver for deployment is discussed. Institutional issues that arise from multi-faceted public sector and private sector participation in ITS implementation are identified and their implications for the implementation strategy are assessed.

Sections 4 and 5 form the crux of the implementation strategy. Here, guidance and recommendations are presented which are sensitive to the definitions and issues raised in the previous sections. As indicated by the titles, sections 4 and 5 are specifically targeted to the state/local implementor and the US DOT respectively.

> *Section 4. State and Local Guidance.* This section provides preliminary implementation guidance to the local stakeholder which will be elaborated and superseded by follow-on activities to the National Architecture program.
>
> *Section 5. DOT Strategy Recommendations.* Focused recommendations are then made to US DOT that are intended to facilitate beneficial, nationally compatible ITS implementations through selective standardization, policy guidance, and strategic investment.

The complementary emphasis of sections 4 and 5 provides focused material for different segments of the intended audience. However, the structure is not meant to segregate the document's audience to individual, self-contained sections. Indeed, each of the sections is interrelated to reflect the often cooperative nature of ITS implementation. An understanding of the architecture and its implications for implementation, from the perspective of any individual stakeholder, is best achieved by reading the entire document with particular attention to the targeted section(s) of interest.

Appendix A. Detailed Market Package Definitions. The market packages that are introduced in section 2 are more fully defined. This section describes the service provided, enumerates major implementation options, and illustrates how the architecture framework supports this service for each defined market package.

Appendix B. Forecast Implementations. This appendix provides a general vision of how the market packages could be provided over time for a representative set of scenarios. These forecasts document efficient deployment sequences that reflect a projected natural evolution of ITS service provision through market development and appropriate public sector decision-making.

Appendix C. Case Studies. Several case studies were performed as part of the Implementation Strategy development effort. Case studies collected and organized data regarding ITS implementations and potential implementors through interviews and secondary research. The case studies cover a representative set of implementations, project scales, institutional settings, and geographic locations to provide a range of real requirements from actual implementors. Case study excerpts are used to illustrate the points made in sections 2 through 5. The full set of case study reports is located in Appendix C.

2. What are the Potential Implementations?

This section introduces the architecture defined by the National ITS Architecture Program and relates this definition to the range of ITS services and implementation options that will be considered by implementors. This relationship between architecture and implementation is presented using a defined set of *Market Packages*.

The technical implications of these implementation choices are then considered and used to identify promising early deployments. These likely candidates for early deployment are identified as *Early Market Packages.* Finally, the implementation choices are related to the Intelligent Transportation Infrastructure initiative. Figure 2-1 shows the general structure of the section and the relationships between each of the subparagraphs.

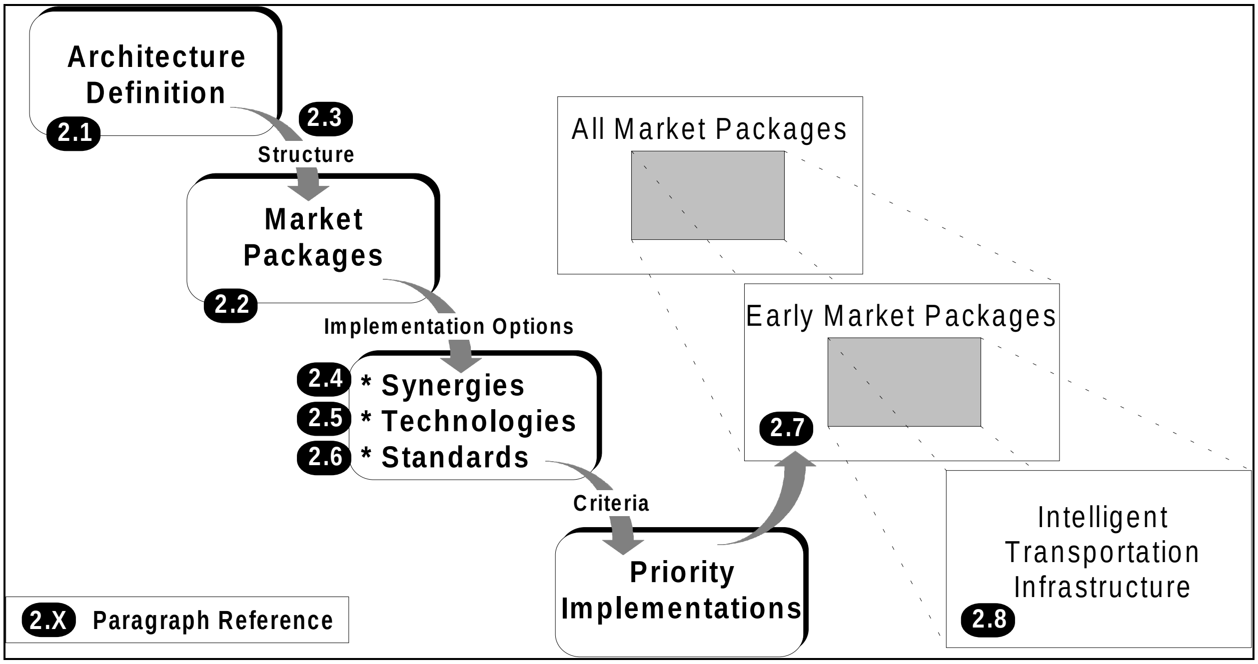


Figure 2-1: Section 2 Content and Sequence

2.1 Architecture Definition

The National ITS Architecture provides a framework for designing transportation systems that implement the ITS User Services. The User Services were developed as part of the National ITS Program Planning process and were the key source requirements for the Architecture Development effort. The architecture defines the functions that must be performed, the subsystems that provide these functions, and the information that must be exchanged to support these User Services. The architecture is comprised of two technical layers, a Transportation Layer and a Communication Layer, which must operate in the context of an Institutional Layer. Figure 2.1-1 illustrates the three layers and their inter-relationships.

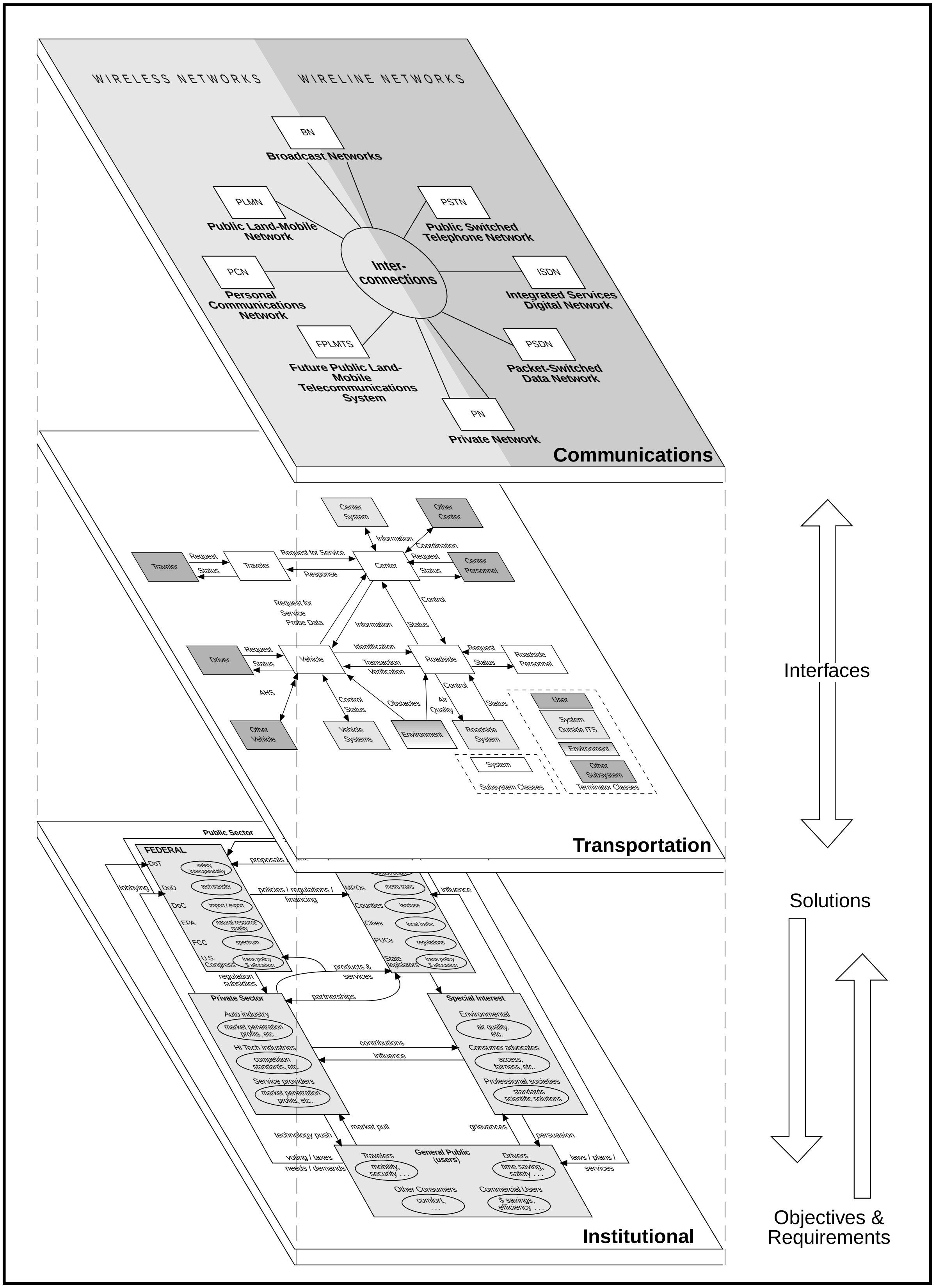


Figure 2.1-1: Architecture Layers

The Transportation Layer includes the various transportation-related processing centers, distributed roadside equipment, vehicle equipment, and other equipment used by the traveler to access ITS services. The Transportation Layer is fully documented in the separate Physical Architecture deliverable. The Communication Layer provides for the transfer of information between the Transportation Layer elements. The technical details associated with the Communication Layer are presented in the Communications Document deliverable. The Transportation and Communication Layers together are the *architecture framework* that coordinates overall system operation by defining interfaces between equipment which may be deployed by different procuring and operating sectors. The Institutional Layer introduces the policies, funding incentives, working arrangements, and jurisdictional structure that support the technical layers of the architecture. The Institutional Layer is fully defined in section 3. This section provides an overview of the architecture framework by presenting the Transportation and Communication Layer definitions in more detail.

The architecture framework defines what each major transportation system element does and how they interact to provide all user services. This framework of subsystems and interfaces is specified in an implementation independent fashion to preserve maximum implementation flexibility.

The benefits of the architecture framework are the benefits of interoperability. For the private sector, interoperability and compatibility create larger markets for ITS products. For public sector and individual consumers of these products, the benefits are reduced costs and more efficient operations through economy of scale and increased competition. Coast to coast utility of ITS services and “mix and match” parts replacement are also primary benefits for the individual consumer. It is important to note that the architecture framework, by itself, will not achieve the desired national interoperability and compatibility goals. To achieve this end, the architecture framework requirements must be interpreted and developed into consensus standards by Standards Development Organizations such as ITE, SAE, and IEEE. This work is on-going.

Figure 2.1-1 provides a high-level view of the architecture framework. The figure includes both the transportation and communication layers of the architecture since it depicts both the subsystems (transportation layer elements) and the major communications interconnects (communication layer elements) required to support the user services

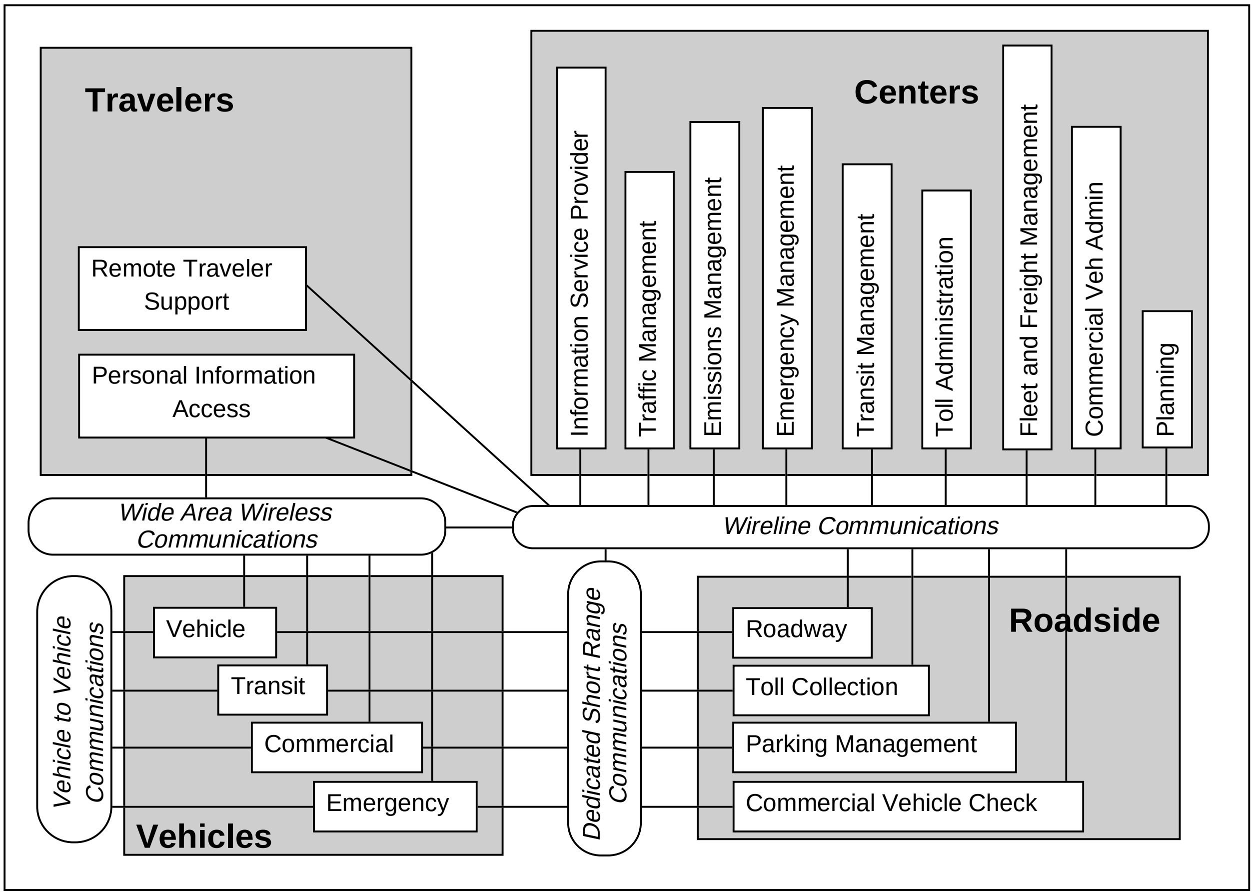


Figure 2.1-2: ITS Architecture Subsystems and Communications

2.1.1 Transportation Layer Architecture

The Transportation Layer includes the nineteen interconnected subsystems identified in Figure 2.1-2. The selected subsystems align closely with existing jurisdictional and physical boundaries that underscore the operation and maintenance of current transportation systems. By mirroring the current transportation environment with the identified subsystems, the subsystem boundaries identify the likely candidates for interface standardization. The architecture recognizes these boundaries to minimize the impact associated with adoption of the architecture. Maximum commonality between existing transportation system boundaries and architecture boundaries serves to minimize the number of artificial boundaries which are imposed (and constrained) by the architecture.

Reference the Physical Architecture document for complete subsystem definitions. Within the Physical Architecture, each subsystem is further decomposed into one or more *equipment packages.* Equipment packages represent the lowest level of decomposition identified by the Physical Architecture.

As illustrated in figure 2.1-2, the subsystems may be grouped into four distinct subsystem classes that share basic functional, deployment, and institutional characteristics. These classes (Centers, Roadside, Vehicles, and Travelers) are used to group top level descriptions for each of the subsystems in this section.

Center Subsystems

The center subsystems provide management, administration, and support functions for the transportation system. The center subsystems each communicate with other centers to enable coordination between modes and across jurisdictions within a region. The center subsystems also communicate with roadside and vehicle subsystems to gather information and provide information and control that is coordinated by the center subsystems.

Before describing the center subsystems in detail, an important distinction must be made between the “center” subsystems and the transportation management “centers” that are familiar to most transportation professionals. In simplest terms, the center subsystems are not “brick and mortar”. Each subsystem is a cohesive set of functional definitions with required interfaces to other subsystems; subsystems are functionally defined, not physically defined. A regional implementation may include a single physical center that collocates the capabilities from several of the center subsystems. For instance, a single Transportation Management Center may include Traffic Management Subsystem, Transit Management Subsystem, Emergency Management Subsystem, and Information Service Provider subsystem capabilities. Conversely, a single subsystem may be replicated in many different physical centers in a complex metropolitan area system. For instance, the traffic management subsystem may be implemented in a traffic management center for freeway control in addition to several distinct city traffic management centers that cooperatively control the arterials. Figure 2.1-3 provides an indication of the range of ways that center subsystems may be implemented in physical centers.

Commercial Vehicle Administration Subsystem

The Commercial Vehicle Administration Subsystem will operate at one or more fixed locations within a region. This subsystem performs administrative functions supporting credentials, tax, and safety regulations. It issues credentials, collects fees and taxes, and supports enforcement of credential requirements. This subsystem communicates with the Fleet and Freight Management Subsystems associated with the motor carriers to process credentials applications and collect fuel taxes, weight/distance taxes, and other taxes and fees associated with commercial vehicle operations. The subsystem also receives applications for, and issues special Oversize/Overweight and HAZMAT permits in coordination with other cognizant authorities. The subsystem coordinates with other Commercial Vehicle Administration Subsystems (in other states/regions) to support nationwide access to credentials and safety information for administration and enforcement functions. This subsystem supports communications with Commercial Vehicle Check Subsystems operating at the roadside to enable credential checking and safety information collection. The collected safety information is processed, stored, and made available to qualified stakeholders to identify carriers and drivers that operate unsafely.

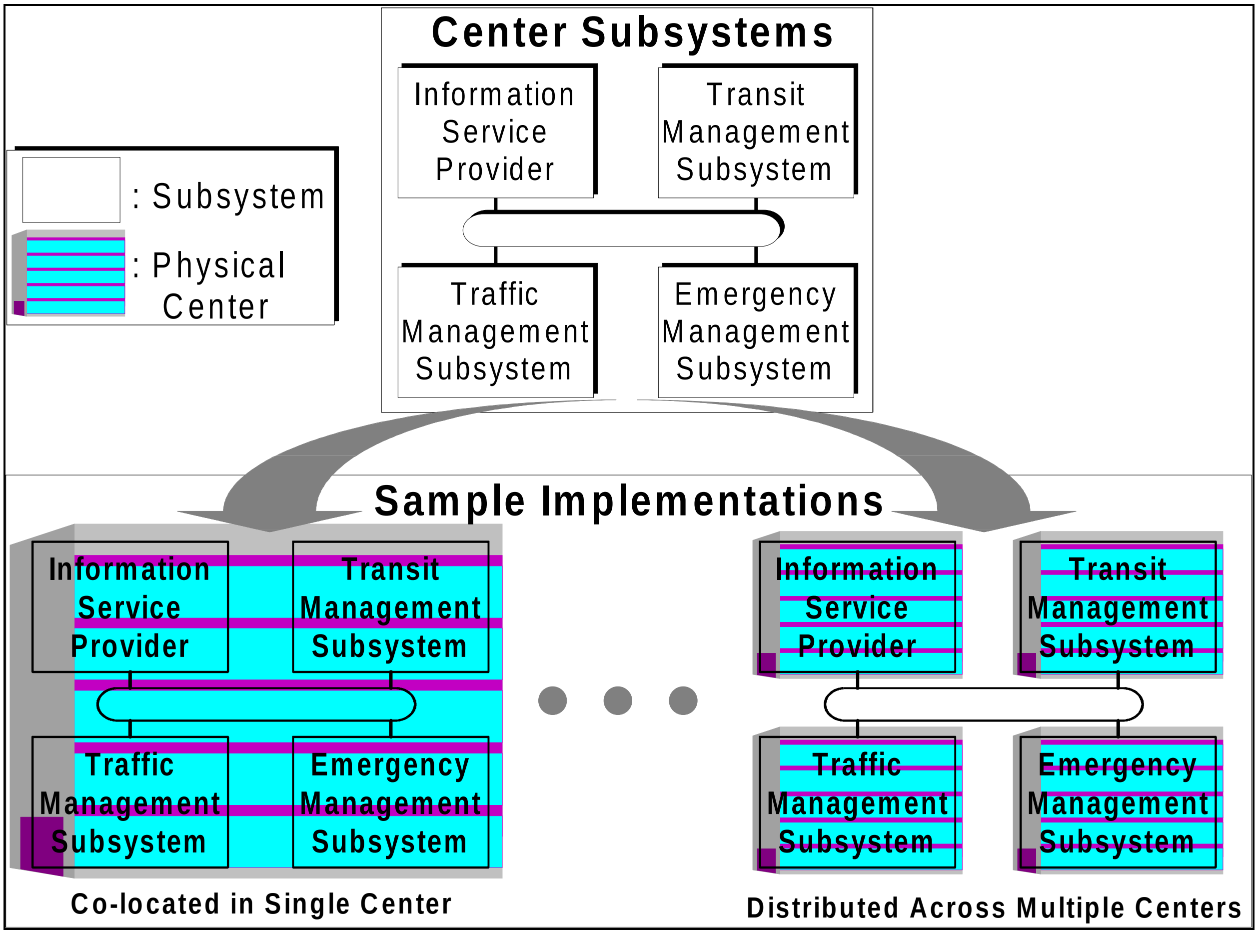


Figure 2.1-3: Center Subsystems May Be Implemented In Various Regional Configurations

Emergency Management Subsystem

The Emergency Management Subsystem operates in various emergency centers supporting public safety including police and fire stations, search and rescue special detachments, and HAZMAT response teams. This subsystem interfaces with other Emergency Management Subsystems to support coordinated emergency response involving multiple agencies. The subsystem creates, stores, and utilizes emergency response plans to facilitate coordinated response. It tracks and manages emergency vehicle fleets. Real-time traffic information received from the other center subsystems is used to further aid the emergency dispatcher in selecting the emergency vehicle(s) and routes that will provide the most timely response. Interface with the Traffic Management Subsystem allows strategic coordination in tailoring traffic control to support en-route emergency vehicles. Interface with the Transit Management Subsystem allows coordinated use of transit vehicles to facilitate response to major emergencies.

Emissions Management Subsystem

This subsystem operates at a fixed location and may co-reside with a Traffic Management Subsystem or may operate in its own distinct location depending on regional preferences and priorities. This subsystem provides the capabilities for air quality managers to monitor and manage air quality. These capabilities include collecting emissions data from distributed emissions sensors within the roadway subsystem. These sensors monitor general air quality within each sector of the area and also monitor the emissions of individual vehicles on the roadway. The sector emissions measures are collected, processed, and used to identify sectors exceeding safe pollution levels. This information is provided to toll administration, traffic management, and transit management systems and used to implement strategies intended to reduce emissions in and around the problem areas. Emissions data associated with individual vehicles, supplied by the Roadway Subsystem, is also processed and monitored to identify vehicles that exceed standards. This subsystem provides any functions necessary to inform the violators and otherwise ensure timely compliance with the emissions standards.

Fleet and Freight Management Subsystem

The Fleet and Freight Management Subsystem manages fleets of commercial vehicles. The subsystem may be a large private trucking firm or a public agency with a fleet of vehicles. Smaller scale implementations oriented towards the independent owner/operator are also supported. The subsystem provides the capability for dispatchers to receive real-time routing information and access databases containing vehicle and cargo locations as well as carrier, vehicle, cargo, and driver information. It provides for the efficient purchase of electronic credentials through automated interface with clearinghouses and regulatory agencies. The Fleet and Freight Management Subsystem may operate either in a firm’s home office through dedicated facilities, or at a truck or rest stop through a public kiosk. These sites communicate with authorities via standard wireline communications. Alternatively, the functions provided by this subsystem could be implemented on a portable computer and managed from the cab of the vehicle using wide area wireless communications.

Information Service Provider Subsystem

This subsystem provides the capabilities to collect, process, store, and disseminate traveler information to subscribers and the public at large. Information provided includes basic advisories, real time traffic condition and transit schedule information, yellow pages information, ridematching information, and parking information. The subsystem also provides the capability to provide specific directions to travelers by receiving origin and destination requests from travelers, generating route plans, and returning the calculated plans to the users. Reservation services are also provided in advanced implementations. The information is provided to the traveler through the Personal Information Access Subsystem, Remote Traveler Support Subsystem, and various Vehicle Subsystems through available communications links. Both basic one-way (broadcast) and personalized two-way information provision is supported. The subsystem provides the capability for an informational infrastructure to connect providers and consumers, and gather that market information needed to assist in the planning of service improvements and in maintenance of operations.

Traffic Management Subsystem

The Traffic Management Subsystem operates within a traffic management center or other fixed location. This subsystem communicates with the Roadway Subsystem to monitor and manage traffic flow. Incidents are detected and verified and incident information is provided to the Emergency Management Subsystem, travelers (through Roadway Subsystem Highway Advisory Radio and Variable Message Signs), and to third party providers. The subsystem supports HOV lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection. The subsystem monitors and manages maintenance work and disseminates maintenance work schedules and road closures. The subsystem also manages reversible lane facilities, and process probe vehicle information. The subsystem communicates with other Traffic Management Subsystems to coordinate traffic information and control strategies in neighboring jurisdictions. It also coordinates with rail operations to support safer and more efficient highway traffic management at highway-rail intersections. Finally, the Traffic Management Subsystem provides the capabilities to exercise control over those devices utilized for AHS traffic and vehicle control.

Toll Administration Subsystem

The Toll Administration Subsystem provides general payment administration capabilities to support electronic assessment of tolls and other transportation usage fees. This subsystem supports traveler enrollment and collection of both pre-payment and post-payment transportation fees in coordination with the existing, and evolving financial infrastructure supporting electronic payment transactions. The system sets up and administers escrow accounts to support pre-payment operations. It supports communications with the Toll Collection Subsystems (and Parking Management Subsystems and Transit Management Subsystems) to support fee collection operations. The subsystem also sets and administers the pricing structures and includes the capability to implement road pricing policies in coordination with the Traffic Management Subsystem. The electronic financial transactions in which this subsystem is an intermediary between the consumer and the financial infrastructure shall be cryptographically protected and authenticated to preserve privacy and ensure authenticity and auditability.

Transit Management Subsystem

The Transit Management Subsystem provides the capability for determining accurate ridership levels and implementing corresponding fare structures. The fare system shall support travelers using a fare medium applicable for all surface transportation services. The subsystem also provides for optimized vehicle and driver assignments, and vehicle routing for fixed and flexibly routed transit services. Interface with the Traffic Management Subsystem control shall be integrated with traffic signal prioritization. This will allow for transit schedule adjustments and automated transit vehicle maintenance management with schedule tracking. The Transit Management Subsystem also provides the capability for automated planning and scheduling of public transit operations. The subsystem shall also provide the capability to furnish travelers with real-time travel information, continuously updated schedules, schedule adherence information, transfer options, and transit routes and fares. In addition, the capability for the monitoring of key transit locations with both video and audio systems shall be provided with automatic alerting of operators and police of potential incidents including support of traveler activated alarms.

Planning Subsystem

The Planning Subsystem accepts data from every center subsystem and uses this data to plan new deployments and new ITS operations. This data also supports policy decision making, allocation of funding, allocation of resources and other planning activities.

Roadside Subsystems

These distributed infrastructure subsystems provide the direct interface to vehicles traveling on the roadway network. Each of the roadside subsystems include functions that must be located on or near the roadway to support direct surveillance, information provision, and control plan execution. All roadside subsystems interface to one or more of the center subsystems which govern overall operation of the roadside subsystems. The roadside subsystems also generally include direct user interfaces to drivers and other travelers on the roadway network as well as short range interfaces to the Vehicle Subsystems.

Commercial Vehicle Check Subsystem

The Commercial Vehicle Check Subsystem supports automated vehicle identification at mainline speeds for credential checking, roadside safety inspections, and weigh-in-motion using two-way data exchange. These capabilities include providing warnings to the commercial vehicle drivers, their Fleet and Freight managers, and proper authorities of any safety problems that have been identified, accessing and examining historical safety data, and automatically deciding whether to allow the vehicle to pass or require it to stop with operator manual override. The Commercial Vehicle Check Subsystem also provides supplemental inspection services to current capabilities by supporting expedited brake inspections, the use of operator hand-held devices, on-board safety database access, and the enrollment of vehicles and carriers in the preclearance program.

Parking Management Subsystem

The Parking Management Subsystem provides the capability to provide parking availability and parking fee information, allow for parking payment without the use of cash with a multiple use medium, and support the detection, classification, and control of vehicles seeking parking.

Roadway Subsystem

This subsystem includes the equipment distributed on and along the roadway which monitors and controls traffic. Equipment includes highway advisory radios, variable message signs, cellular call boxes, CCTV cameras and video image processing systems for incident detection and verification, vehicle detectors, traffic signals, grade crossing warning systems, and freeway ramp metering systems. This subsystem also provides the capability for emissions and environmental condition monitoring including weather sensors, pavement icing sensors, fog etc. HOV lane management and reversable lane management functions are also available. In advanced implementations, this subsystem supports automated vehicle safety systems by safely controlling access to and egress from an Automated Highway System through monitoring of, and communications with, AHS vehicles. Intersection collision avoidance functions are provided by determining the probability of a collision in the intersection and sending appropriate warnings and/or control actions to the approaching vehicles.

Toll Collection Subsystem

The Toll Collection Subsystem provides the capability for vehicle operators to pay tolls without stopping their vehicles using pricing structures for locally determined needs and including the capability to implement various variable road pricing policies. Transactions to each customer shall be provided a confirmation and implemented to minimize fraud by supporting vehicle identification technologies and accommodating single billing to commercial carriers.

Vehicle Subsystems

These subsystems are all vehicle-based and share many general driver information, vehicle navigation, and advanced safety systems functions. The vehicle subsystems communicate with the roadside subsystems and center subsystems for provision of information to the driver. In the following descriptions, the Vehicle Subsystem description includes general traveler information and vehicle safety functions that are also applicable to the three fleet vehicle subsystems (Commercial Vehicle Subsystem, Emergency Vehicle Subsystem, and Transit Vehicle Subsystem). The fleet vehicle subsystems all include vehicle location and two-way communications functions that support efficient fleet operations. Each of the three fleet vehicle subsystems also include functions that support their specific service area

Vehicle Subsystem

This subsystem resides in an automobile and provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and convenient travel by personal automobile. Information services provide the driver with current travel conditions and the availability of services along the route and at the destination. Both one-way and two-way communications options support a spectrum of information services from low-cost broadcast services to advanced, pay for use personalized information services. Route guidance capabilities assist in formulation of an optimal route and step by step guidance along the travel route. Advanced sensors, processors, enhanced driver interfaces, and actuators complement the driver information services so that, in addition to making informed mode and route selections, the driver travels these routes in a safer and more consistent manner. Initial collision avoidance functions provide “vigilant co-pilot” driver warning capabilities. More advanced functions assume limited control of the vehicle to maintain safe headway. Ultimately, this subsystem supports completely automated vehicle operation through advanced communications with other vehicles in the vicinity and in coordination with supporting infrastructure subsystems. Pre-crash safety systems are deployed and emergency notification messages are issued when unavoidable collisions do occur.

Commercial Vehicle Subsystem

This subsystem resides in a commercial vehicle and provides the sensory, processing, storage, and communications functions necessary to support safe and efficient freight movement. The Commercial Vehicle Subsystem provides two-way communications between the commercial vehicle drivers, their fleet managers, and roadside officials, and provides HAZMAT response teams with timely and accurate cargo contents information after a vehicle incident. This subsystem provides the capability to collect and process vehicle, cargo, and driver safety data and status and alert the driver whenever there is a potential safety problem. Basic identification and safety status data are supplied to inspection facilities at mainline speeds. In addition, the subsystem will automatically collect and record mileage, fuel usage, and border crossings.

Emergency Vehicle Subsystem

This subsystem resides in an emergency vehicle and provides the sensory, processing, storage, and communications functions necessary to support safe and efficient emergency response. The Emergency Vehicle Subsystem includes two-way communications to support coordinated response to emergencies in accordance with an associated Emergency Management Subsystem. Emergency vehicles are equipped with automated vehicle location capability for monitoring by vehicle tracking and fleet management functions in the Emergency Management Subsystem. Using these capabilities, the appropriate emergency vehicle to respond to each emergency is determined. Route guidance capabilities within the vehicle enable safe and efficient routing to the emergency. In addition, the emergency vehicle may be equipped to support signal preemption through communications with the roadside subsystem.

Transit Vehicle Subsystem

This subsystem resides in a transit vehicle and provides the sensory, processing, storage, and communications functions necessary to support safe and efficient movement of passengers. The Transit Vehicle Subsystem collects accurate ridership levels and supports electronic fare collection. An optional traffic signal prioritization function communicates with the roadside subsystem to improve on-schedule performance. Automated vehicle location functions enhance the information available to the Transit Management Subsystem enabling more efficient operations. On-board sensors support transit vehicle maintenance. The Transit Vehicle Subsystem also furnishes travelers with real-time travel information, continuously updated schedules, transfer options, routes, and fares.

Traveler Subsystems

The traveler subsystems include the equipment that is used by the traveler to gather information and access other personal information services prior to a trip and while en-route. The class includes elements that are owned and operated by the traveler as well as elements that are owned by transportation providers and information providers. Though the equipment owned by the traveler (e.g., personal computer, personal digital assistant) is often general purpose and used for a variety of tasks, this equipment is specifically used for gaining access to traveler information within the scope of the ITS architecture. These subsystems interface to the information provider (one of the center subsystems, most commonly the Information Service Provider Subsystem) to access the traveler information. A range of service options and levels of equipment sophistication are supported.

Personal Information Access Subsystem

This subsystem accesses traveler information at home, at work, and other locations frequented by the traveler using personal fixed and portable devices over multiple types of electronic media. Radio, television, personal computers, personal digital assistants, telephones, and any other communications-capable consumer products that can be used to supply information to the traveler are all encompassed by this subsystem definition. Sophistication ranges from simple receipt of broadcast advisories to advanced interactive capabilities which enables users to receive route plans and other real-time information tailored to their individual needs. Other available capabilities include Mayday and real-time reservation services.

Remote Traveler Support Subsystem

This subsystem provides access to traveler information at transit stations, transit stops, other fixed sites along travel routes, and at major trip generation locations such as special event centers, hotels, office complexes, amusement parks, and theaters. Traveler information access points include kiosks and informational displays supporting varied levels of interaction and information access. At transit stops, simple displays provide schedule information and imminent arrival signals. This basic information may be extended to include multi-modal information including traffic conditions and transit schedules along with yellow pages information to support mode and route selection at major trip generation sites. Personalized route planning and route guidance information can also be provided based on criteria supplied by the traveler. In addition to traveler information provision, this subsystem also supports public safety monitoring using CCTV cameras or other surveillance equipment and emergency notification within public areas. Fare card maintenance, and other features which enhance traveler convenience may also be provided at the discretion of the deploying agency.

2.1.2 Communication Layer Architecture

The Communication Layer provides information transfer for the Transportation Layer subsystems. It includes all of the communications entities (e.g., wireline and wireless transmitters, receivers, satellites) and the information management and transport capabilities necessary to transfer information among the transportation entities. The application data content and the transportation application requirements are, in general, transparent to the communication architecture. The communication architecture's view of the transportation layer is that of many distributed users, some of them mobile, which require communication services.

Due to variation in the ITS user service requirements (from a communication perspective), ITS implementations will require a range of communication services. Specifically, some ITS user services will be best served by leveraging commercial telecommunication infrastructures, others will require specialized, dedicated communication systems. The differences in these architectural choices can lead to dramatic differences in cost, deployability, and performance.

The "Communication Services" that are provided by the Communication Layer are defined according to communications governing bodies and should not be confused with the ITS user services. The communication services define the exchange of information between two points and are independent of the media and application. In essence, they are a set of information transfer capabilities provided by the Communication Layer to a user in the Transportation Layer. Figure 2.1-4 illustrates the hierarchy of communication services. A brief description of the services follows; more detailed definitions are provided in the Communications Document..

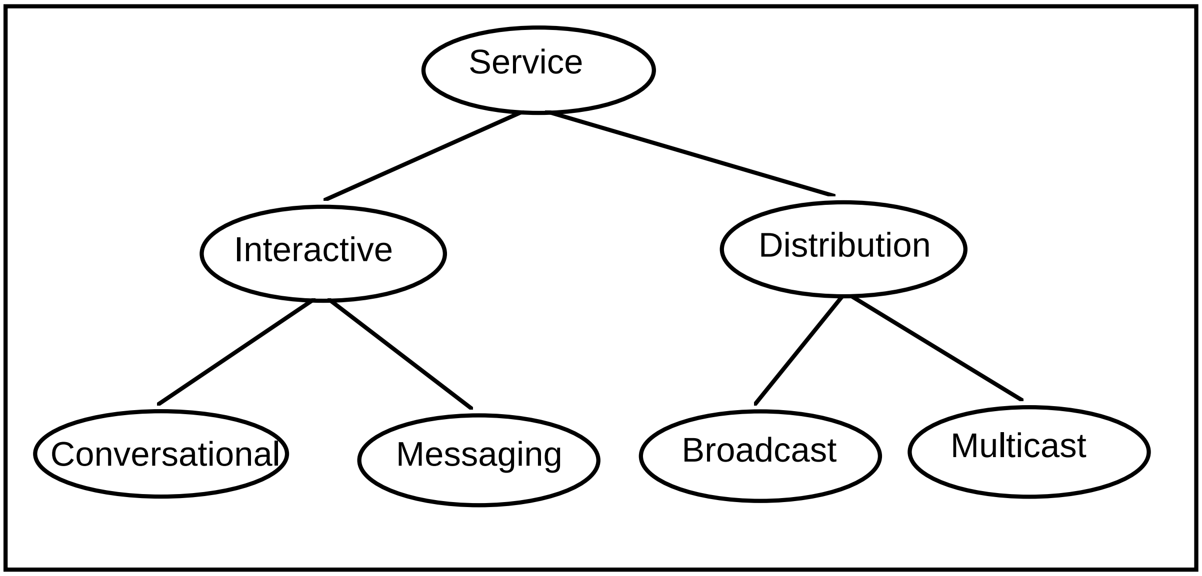


Figure 2.1-4 Communication Services Hierarchy

Communication services consist of two broad categories, interactive and distribution. Interactive services allow the user to exchange data with other users or providers in real or near real time, asking for service or information and receiving it in the time it takes to communicate or look up the information. Distribution services allow the user to send the same message to multiple other users.

Interactive services may be either conversational or messaging. Conversational implies the use of a two-way connection established before information exchange begins and terminated when the exchange is completed. Messaging, on the other hand, works more like electronic mail being exchanged between users. The messages are exchanged without establishing a dedicated path between the two sites. Each message is addressed and placed on the network for transmission, intermixed with messages from other users. The communications community labels this mode of communication a “datagram” service.

Distribution services may be either broadcast or multicast and may be used over wireline and/or wireless communication links. Broadcast messages are those sent to all users while multicast messages are sent only to a subset of users. Multicast differs from broadcast in its use of a designated address for all users and user groups. Examples of broadcast information might include current weather or road conditions, whereas multicast information might be information sent to all drivers working for a specific company. A changing group membership could be the set of users traveling between two locations or with a certain destination, for which unique information must be transmitted. The services that can be supported using circuit or packet connection mode include voice, video, image and data.

The relationship between the Communication Layer and the Transportation Layer is presented in the generic hierarchical communication model in Figure 2.1-5. The figure follows the Open Systems Interconnection model which is structured as a series of layers, each providing certain services to the layer above and capable of conversing with the corresponding layer at the other end of the link. Thus the high level layers (e.g., ITS application) are shielded from the actual implementation details of the communication services. Different networks can use layers different from the OSI model, such as the IBM SNA (Systems Network Architecture). When different protocols are used in different networks, an interworking function must provide the conversion between the protocols at the various levels.

The ITS users in the figure are the Transportation Layer subsystems which share information. The Transportation Layer user is not concerned with the specifics of the information transfer performed by the Communication Layer. In fact, the Communication Layer can be viewed as plumbing that transparently carries information between users. Communications Service requirements are assigned in the Communication Layer for each data flow that is defined in the Transportation Layer.

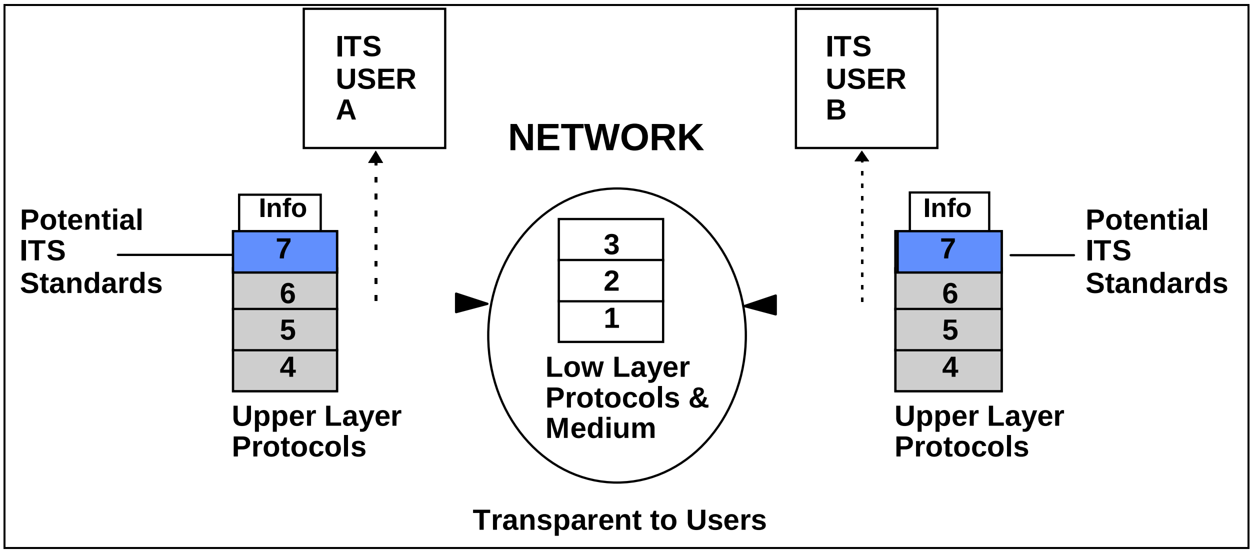


Figure 2.1-5 Generic Hierarchical Communication Model

In general, the communication architecture has two components: one wireless and one wireline. All Transportation Layer entities requiring information transfer are supported by one or both of these components. In most cases, the wireless component merely provides a tetherless user, usually one in a vehicle, with access to fixed (or wireline) network resources. The wireless portion is manifested in three different ways. Each of the four identified interface types (three wireless and one wireline) are defined as follows:

- **Wide Area Wireless Communications** defines cell-based wireless infrastructures supporting wide-area information transfer (most data flows). The cell-based airlink, from a mobile terminal to one of a set of base stations, provides connections between mobile users or between mobile and fixed network-connected users (e.g., those connected to the telephone network). It is typified by the current cellular telephone network, the larger cells of Specialized Mobile Radio, and PCS. This interface type also includes one-way broadcast wireless communications systems used to provide basic traveler information across a wide-area. Both voice and data communications are included. FM Subcarrier is a prime example of a data capable, broadcast communications technology that would be included.
- **Dedicated Short Range Communications** defines the short-range airlink used for close-proximity (less than 50-100 feet) transmissions between a mobile user and a base station, typified by transfers of vehicle identification numbers at toll booths.
- **Vehicle to Vehicle Communications** addresses the dedicated wireless system handling high data rate, low probability of error, line of sight, AHS-related data flows, such as vehicle to vehicle transceiver radio systems.
- **Wireline Communications** addresses the information transfer between two fixed entities. Typically, this interface will be manifested using one of the many alternative existing public or private networks that may physically include wireless (e.g. microwave) as well as wireline infrastructure.

Figure 2.1-2, included at the beginning of this section, showed the allocation of these basic communications types to the interfaces between the Transportation Layer subsystems.

2.2 Market Packages

The architecture definition presented in the previous section is intended to be extremely accommodating.

- It supports the complete range of ITS services from basic signal control improvements to Automated Highway Systems.
- It is scaleable so that implementations that are suitable for the nations largest population centers as well as the most remote rural areas are supported with equal aplomb.
- It is specified in a technology independent manner so that a range of current and future technologies can be supported by the framework.

All this flexibility is necessary since the architecture must accommodate the range of possible ITS implementations from coast to coast and over a twenty year timeframe. Unfortunately, this flexibility also makes it difficult to understand precisely what pieces of the architecture are applicable and how they can best be applied in solving a particular communities current transportation problems (see figure 2.2-1).

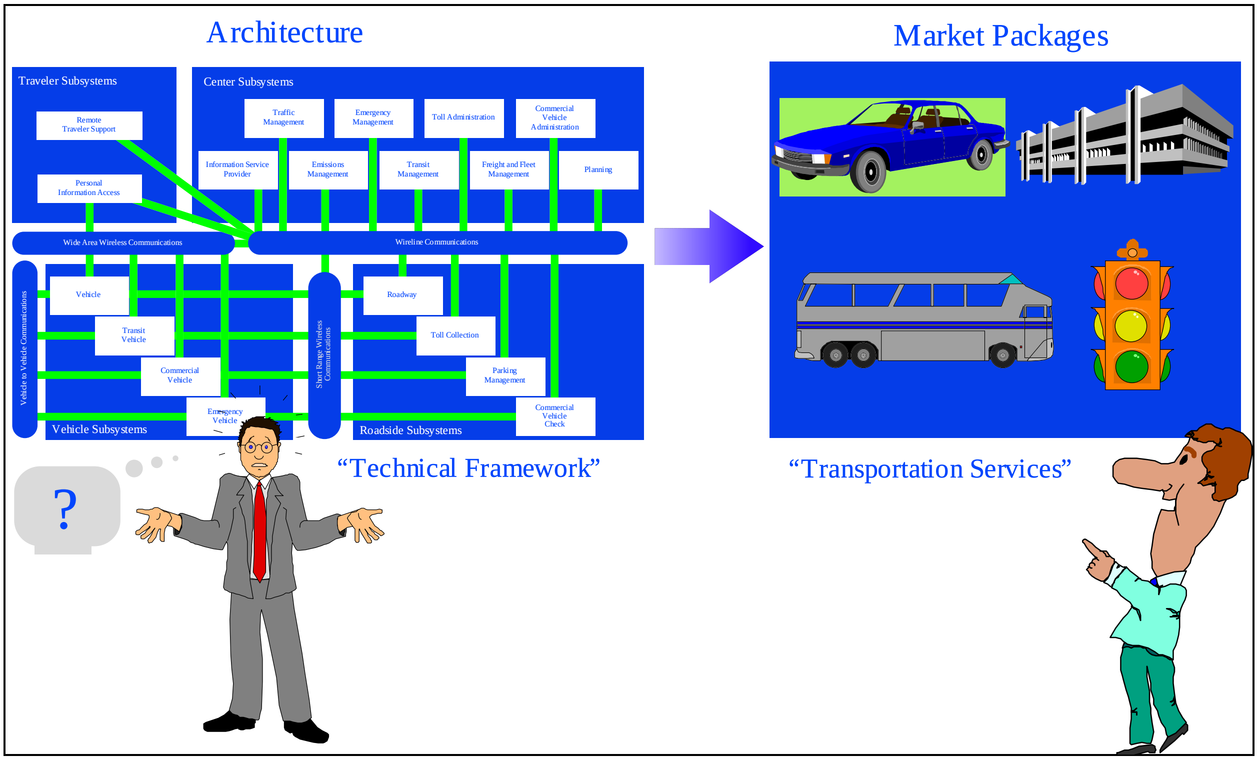


Figure 2.2-1: Translating Architecture to Implementation Through Market Packages

To provide visibility into the service options that will be considered by the ITS implementor, a set of *market packages* have been defined. The market packages provide an accessible, deployment oriented perspective to the national architecture. They are tailored to fit - separately or in combination - real world transportation problems and needs. They address the specific service requirements of traffic managers, transit operators, travelers, and other ITS stakeholders. The market packages were defined with enough granularity to support specific benefits analysis with clear ties to transportation problems.

Several different market packages are defined in each major application area which provides a palette of service options at various costs. Market packages are also structured to segregate services that are likely to encounter technical or non-technical challenges from lower risk services. This approach identifies a subset of the market packages that are likely early deployments. At the other end of the spectrum, several of the market packages represent advanced products or services that will not be available for some time. Many of the market packages are also incremental so that more advanced packages can be efficiently implemented by building on common elements that were deployed earlier with more basic packages.

The complete set of market packages are identified in Table 2.2-1. In order to more accurately specify market packages in tables, each is given an abbreviation indicating the general class of stakeholder and an index (e.g., ATMS1 is a market package primarily of interest to transportation managers).

Table 2.2-1: Market Packages Summary

Market Package	Market Package Name
ATMS01	Network Surveillance
ATMS02	Probe Surveillance
ATMS03	Surface Street Control
ATMS04	Freeway Control
ATMS05	HOV and Reversible Lane Management
ATMS06	Traffic Information Dissemination
ATMS07	Regional Traffic Control
ATMS08	Incident Management System
ATMS09	Traffic Network Performance Evaluation
ATMS10	Dynamic Toll/Parking Fee Management
ATMS11	Emissions and Environmental Hazards Sensing
ATMS12	Virtual TMC and Smart Probe Data
ATMS13	Standard Railroad Grade Crossing
ATMS14	Advanced Railroad Grade Crossing
ATMS15	Railroad Operations Coordination
APTS1	Transit Vehicle Tracking
APTS2	Transit Fixed-Route Operations
APTS3	Demand Response Transit Operations
APTS4	Transit Passenger and Fare Management
APTS5	Transit Security
APTS6	Transit Maintenance
APTS7	Multi-modal Coordination
ATIS1	Broadcast Traveler Information
ATIS2	Interactive Traveler Information

Market Package	Market Package Name
ATIS3	Autonomous Route Guidance
ATIS4	Dynamic Route Guidance
ATIS5	ISP Based Route Guidance
ATIS6	Integrated Transportation Management/Route Guidance
ATIS7	Yellow Pages and Reservation
ATIS8	Dynamic Ridesharing
ATIS9	In Vehicle Signing
AVSS01	Vehicle Safety Monitoring
AVSS02	Driver Safety Monitoring
AVSS03	Longitudinal Safety Warning
AVSS04	Lateral Safety Warning
AVSS05	Intersection Safety Warning
AVSS06	Pre-Crash Restraint Deployment
AVSS07	Driver Visibility Improvement
AVSS08	Advanced Vehicle Longitudinal Control
AVSS09	Advanced Vehicle Lateral Control
AVSS10	Intersection Collision Avoidance
AVSS11	Automated Highway System
CVO01	Fleet Administration
CVO02	Freight Administration
CVO03	Electronic Clearance
CVO04	CV Administrative Processes
CVO05	International Border Electronic Clearance
CVO06	Weigh-In-Motion
CVO07	Roadside CVO Safety
CVO08	On-board CVO Safety
CVO09	CVO Fleet Maintenance
CVO10	HAZMAT Managment
EM1	Emergency Response
EM2	Emergency Routing
EM3	Mayday Support
ITS1	ITS Planning

As will be seen in section 2.3, the deployment-oriented market packages are traceable to the interface-oriented architecture definition. Once a particular market package is selected for implementation, the required subsystems, equipment packages, and interface requirements may be identified through this traceability. This approach allows the implementor (and this document) to first consider deployment options and later concentrate on those pieces of the architecture necessary to support the selected deployment.

It is important to note that the market packages are illustrative rather than prescriptive. The actual implementation variations that are possible across the country are myriad and cannot be enumerated through a concise set of packages. The market packages are tools that allow this

Implementation Strategy to discuss incremental deployment of ITS services in a manner that is relevant to the underlying architecture definition.

So that the reader develops a general feel for the market packages and how they relate to the architecture and to each other, several examples are presented in this section. Appendix A provides detailed definitions for all of the market packages.

The example market packages that are presented in this section illustrate the range of route guidance implementations supported by the architecture. The four route guidance market packages incrementally build on one another to provide a progressive set of capabilities that can be incrementally deployed over time. Alternatively, the four market packages represent the varied levels of infrastructure support that a route guidance system may encounter as it travels across the country some time in the future.

The route guidance series of market packages begins with the Autonomous Route Guidance package which provides a self-contained route guidance service. Initial infrastructure support is provided by a second incremental Dynamic Route Guidance market package which adds the capability to broadcast real-time updates from the infrastructure to the mobile route guidance equipment. The third market package, ISP-Based Route Guidance, supports direct provision of route plans from the infrastructure. This market package can reduce the cost of in-vehicle equipment since it removes the requirement for route plan calculation from the vehicle. It also enables more explicit infrastructure control of the route selection process which has the potential to enhance network performance. Building on this latter potential, the most advanced route guidance market package tightly integrates the centralized route planning capability with area-wide traffic control for further enhancements in overall system performance.

The incremental nature of the route guidance market packages is readily seen through a comparison of the subsystems, equipment packages, and interfaces that support each. The following pages describe each of the four route guidance market packages in turn. In each example, a description of the service offered by each market package is coupled with a graphic that identifies how the architecture framework supports the market package. Where alternative implementation options are supported by the market package, these are also identified and differentiated in the descriptions.

Figure 2.2-2 provides a legend to assist in interpretation of the sample market package diagrams. Only the most salient elements from the architecture definition (e.g., directly involved subsystems, system terminators, and the highest level data flows) are depicted in each graphic to improve clarity.

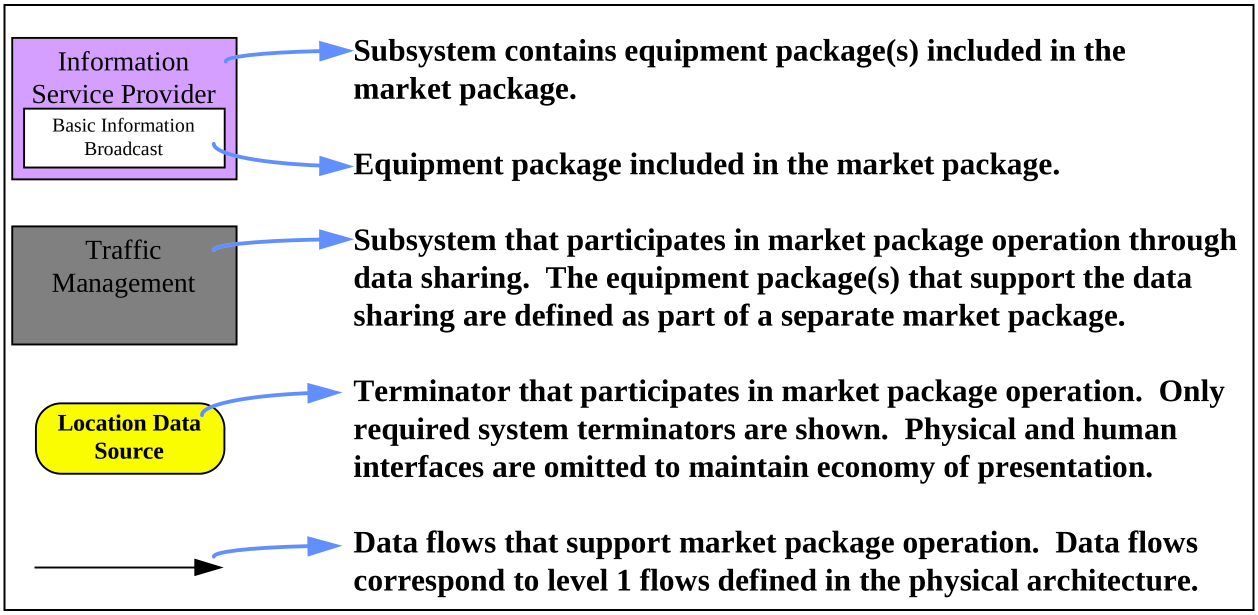
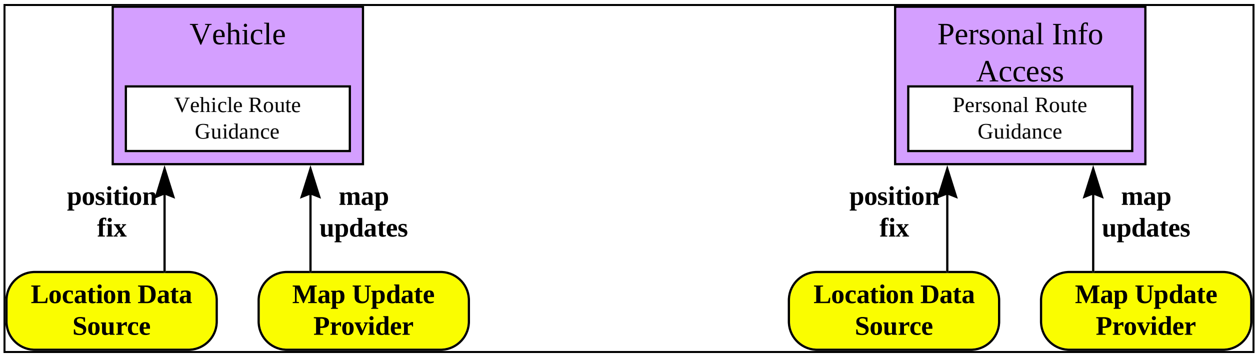


Figure 2.2-2: Market Package Diagram Elements

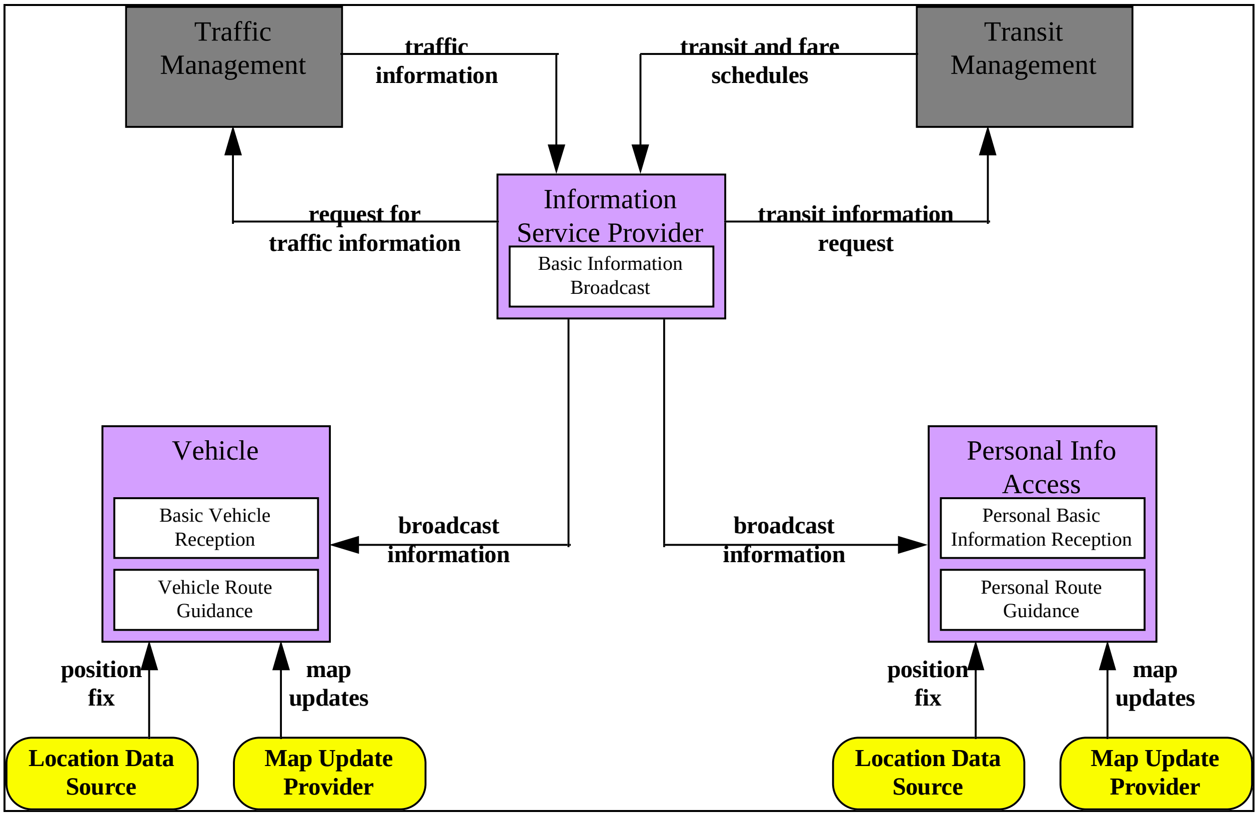
Autonomous Route Guidance (ATIS3)

This market package relies on in-vehicle sensory, location determination, computational, map database, and interactive driver interface equipment to enable route planning and detailed route guidance based on static, stored information. No communication with the infrastructure is assumed or required. Identical capabilities are available to the traveler outside the vehicle by integrating a similar suite of equipment into portable devices.



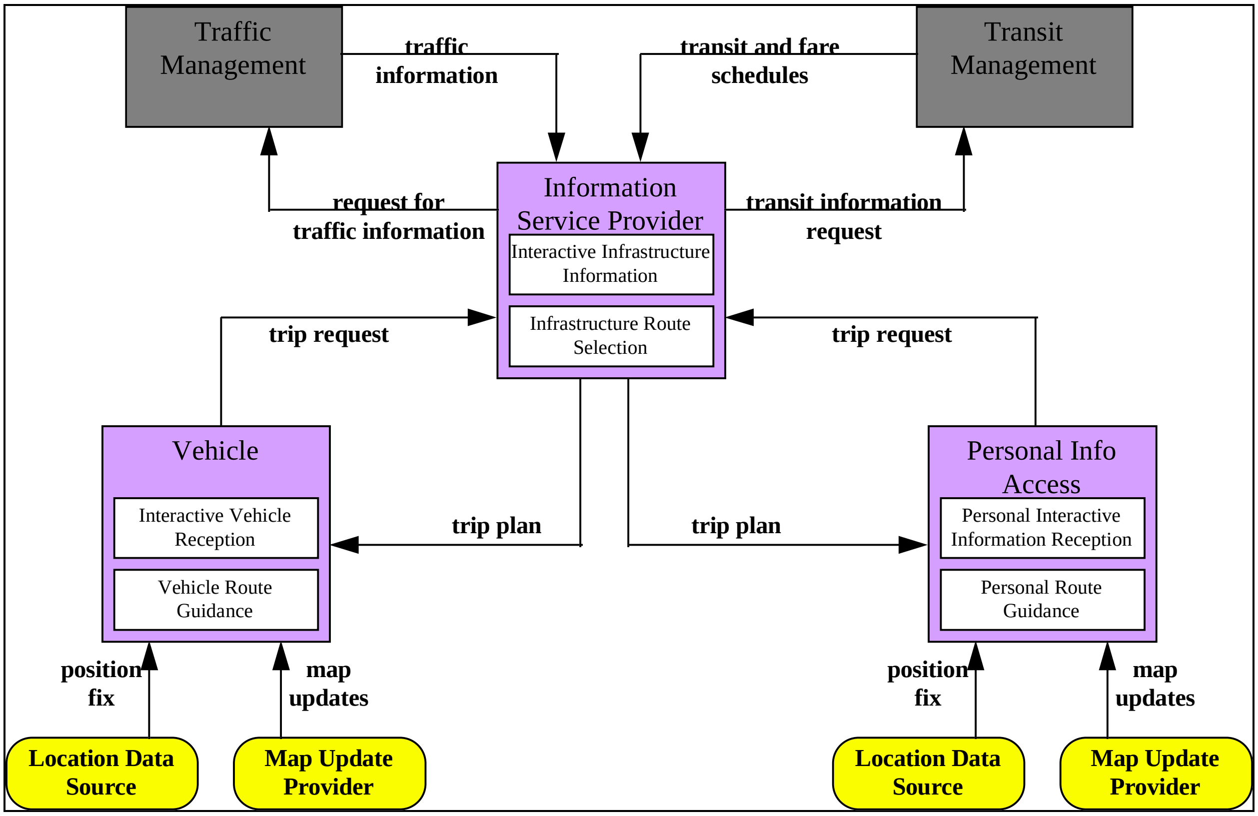
Dynamic Route Guidance (ATIS4)

This market package offers the user advanced route planning and guidance which is responsive to current conditions. The package combines the autonomous route guidance user equipment with a digital receiver capable of receiving real-time traffic, transit, and road condition information which is considered by the user equipment in provision of route guidance.



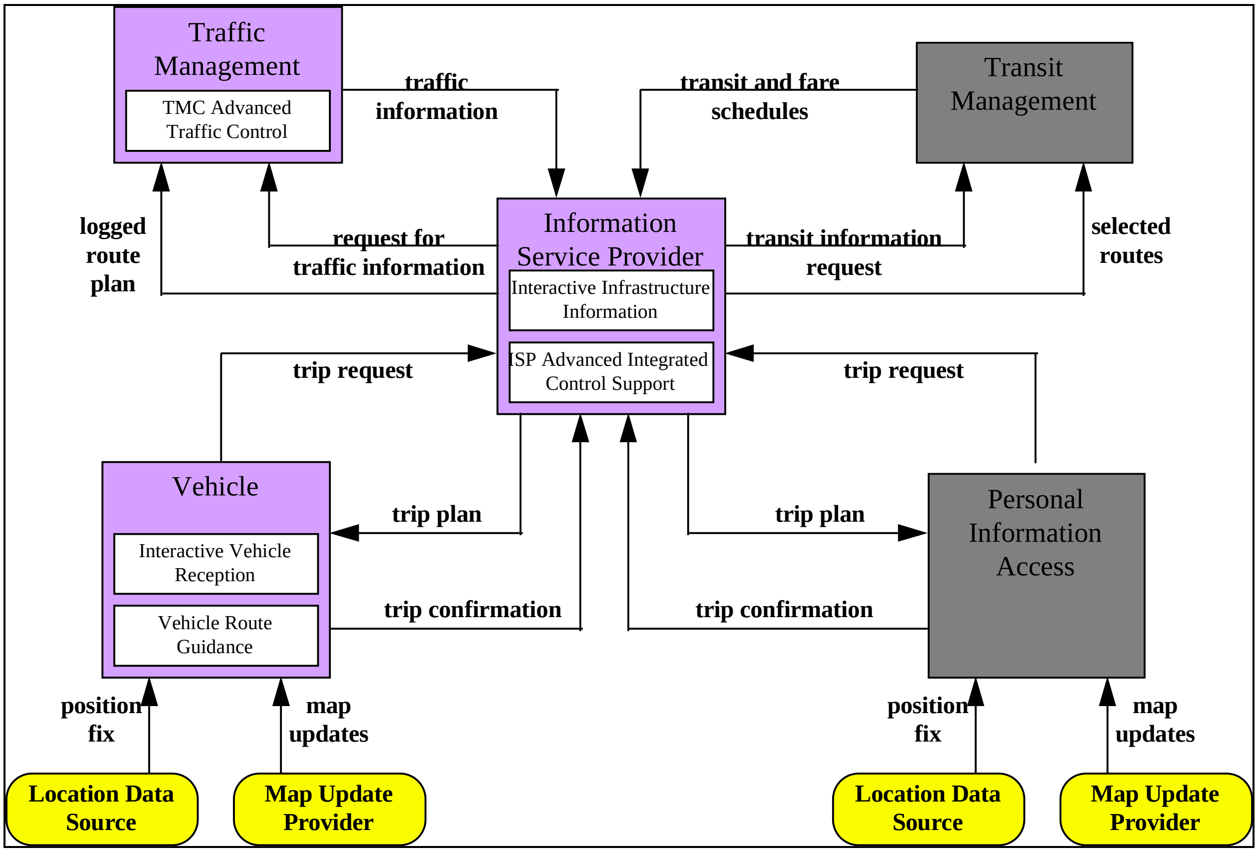
ISP-Based Route Guidance (ATIS5)

This market package moves the route planning function from the user device to the information service provider. This approach simplifies the user equipment requirements and can provide the infrastructure better information on which to predict future traffic and appropriate control strategies. The package includes two way data communications and optionally also equips the user with the data bases, location determination capability, and display technology to support turn by turn route guidance.



Integrated Transportation Management/Route Guidance (ATIS6)

This market package extends the level of coordination between the Information Service Provider and Traffic Management Subsystem. This additional coordination allows the traffic management subsystem to continuously optimize the traffic control strategy based on near-real time information on intended routes for a proportion of the vehicles within their network. It would utilize this ISP-provided route planning information to optimize traffic management strategies while at the same time providing updated signal timing information back to the ISP to allow optimized route plans.



2.3 Relating Market Packages to the Architecture Definition

The market packages are directly traceable to both the architecture framework presented in section 2.1 and the user services which were the source requirements for the National Architecture. This section connects each of these elements.

A market package is implemented with a combination of interrelated equipment; this equipment often resides in several different subsystems within the architecture framework and may be operated by different stakeholders. For instance, the Transit Vehicle Tracking market package includes vehicle location equipment in the Transit Vehicle Subsystem and a base station element in the Transit Management Subsystem. In this example, all market package elements are owned and operated by the same transit stakeholder.

In other cases, the market package elements are owned and operated by different stakeholders. Many of the ATIS market packages require equipment in the Information Service Provider Subsystem that is owned and operated by a public or private information provider and equipment that is acquired and operated by the consumer as part of the Vehicle Subsystem or Personal Information Access Subsystem. Since equipment in different subsystems may be purchased and operated by different end-users, these subsystem-specific components may encounter varied deployment.

To understand and analyze these potential deployment variations, the defined market packages must be decomposed to their constituent elements. The portion of the market package capabilities that are allocated to each subsystem are segregated and defined as equipment packages to support this additional resolution. An *equipment package* represents a set of equipment/capabilities which are likely to be purchased by an end-user to achieve a desired capability.

Since equipment packages are both the most detailed elements of the physical architecture and associated with specific market packages, there is clear traceability between the interface-oriented architecture framework and the deployment-oriented market packages. Figure 2.3-1 depicts the relationship between the user services, architecture elements, and market packages.

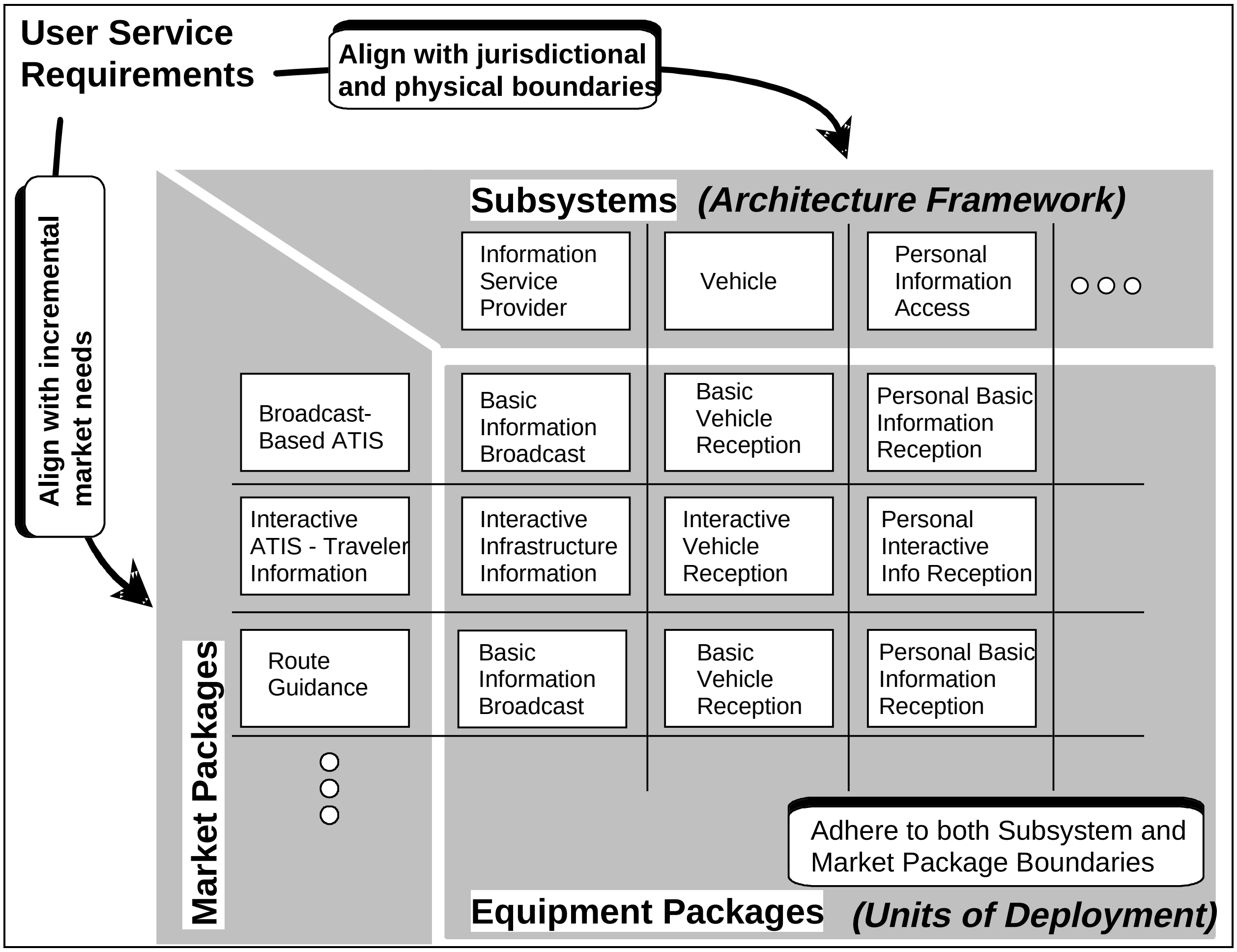


Figure 2.3-1: Architecture Element Relationships

Table 2.3-1 provides a complete listing of the equipment packages for each valid market package/subsystem combination. In the table, the rows represent the defined market packages, the columns represent the subsystems, and the center section of the table identifies the associated equipment packages. Related market packages are grouped along the left side so the reader can see the total set of equipment packages which make up a particular market package deployment. The Physical Architecture deliverable provides detailed specifications for each of the equipment packages identified in the table.

The market packages are also directly traceable to the user services. A market package often includes capabilities which span more than one user service. A single user service sometimes includes a range of incremental capabilities that are segregated into separate market packages so that they can be considered separately from a deployment perspective. As a result, there is a many to many relationship between the market packages and the user services.

To illustrate these relationships with examples:

- The Traffic Control user service requires distinct surveillance, freeway and surface street traffic control, integrated area-wide traffic control, HOV lane control, and traffic information dissemination capabilities. Each of these capabilities may be deployed individually by a local jurisdiction and are allocated to distinct market packages. The market packages also distinguish between different traffic surveillance approaches: Roadside instrumentation (Network Surveillance Market Package) and vehicle probes (Probe Surveillance Market Package) are separated due to fundamentally different technical and institutional issues for the two approaches. In total, eleven separate market packages provide different mechanisms and levels of support for satisfying the Traffic Control user service requirements.

- The HOV and Reversible Lane Management Market Package supports both the traffic control and Travel Demand Management user services since both services require HOV lane management capabilities. This single deployable package satisfies portions of the requirements associated with both of these user services.

The association between user services and market packages is presented in Table 2.3-2. As shown in the table, the identified market packages support all required user services.

Table 2.3-1: Mapping Market Packages, Subsystems, and Equipment Packages

Market Packages	Subsystems																		
	Commercial Vehicle Admin	**Commercial Vehicle Check**	**Commercial Vehicle Subsys**	**Emergency Management**	**Emergency Vehicle Subsys**	**Emissions Management**	**Fleet and Freight Management**	**Information Service Provider**	**Parking Management**	**Personal Info Access**	**Planning Subsystem**	**Remote Traveler Support**	**Roadway Subsystem**	**Toll Administration**	**Toll Collection**	**Traffic Management**	**Transit Management**	**Transit Vehicle Subsystem**	**Vehicle**
Network Surveillance													Roadway Basic Surveillance			Collect Traffic Surveillance			
Probe Surveillance								Interactive Infrastructure Info, ISP Probe Information Collection					Roadway Probe Beacons			TMC Probe Information Collection			Interactive Vehicle Reception, Probe Vehicle Software, Vehicle Toll/Parking interface
Surface Street Control													Roadway Signal Controls			TMC Basic Signal Control, Traffic Maintenance			
Freeway Control													Roadway Freeway Control, Roadway Incident Detection			TMC based freeway control, TMC Incident Detection, Traffic			
HOV and Reversible Lane Management													Roadway HOV Usage, Roadway Reversible Lanes			TMC HOV/Reversible Lane Management			
Traffic Information Dissemination													Roadway Traffic Information Dissemination			TMC Traffic Information Dissemination			
Regional Traffic Control																TMC Regional Traffic Control			
Incident Management System				Emergency Response Management												TMC Incident Dispatch Coordination/Communication			
Traffic Network Performance Evaluation																TMC Traffic Network Performance Evaluation			
Dynamic Toll/Parking Fee Management									Parking Management					Toll Administration	Toll Plaza Toll Collection	TMC Toll/Parking Coordination			Vehicle Toll/Parking Interface
Emissions and Environmental Hazards Sensing						Emissions and Environmental Data Management							Roadway Pollution and Environmental Hazards Indicators						
Virtual TMC and Smart Probe Data													Automated road signing, Roadway Probe Beacons			Distributed Road Management			In-vehicle Signing System, Smart Probe
Standard Railroad Grade Crossing													Standard Rail Crossing			HRI Traffic Management			
Advanced Railroad Grade Crossing													Advanced Rail Crossing			HRI Traffic Management			
Railroad Operations Coordination																Rail Operations Coord HRI Traffic Mgmt			
Transit Vehicle Tracking																	Transit Center Tracking and	On-board Trip Monitoring	
Transit Fixed-Route Operations																	Transit Center Fixed-Route Operations	Vehicle Dispatch Support	
Demand Response Transit Operations								Interactive Infrastructure Info		Personal Interactive Information Reception		Remote Interactive Information Reception					Transit Center Paratransit Operations	On-board Transit Driver I/F	
Transit Passenger and Fare Management												Remote Transit Fare Management					Transit Center Fare and Load Management	On-board Transit Fare and Load Management	
Transit Security				Emergency Response Management								Remote Transit Security I/F					Transit Center Security	On-board Transit Security	
Transit Maintenance																	Fleet Maintenance Management	On-board Maintenance	
Multi-modal Coordination													Roadside Signal Priority			TMC Multi-Modal Coordination	Transit Center Multi-Modal Coordination	On-board Vehicle Signal Coordination	
Broadcast Traveler Information								Basic Information Broadcast		Personal Basic Information Reception		Remote Basic Information Reception							Basic Vehicle Reception
Interactive Traveler Information								Interactive Infrastructure Info		Personal Interactive Information Reception		Remote Interactive Information Reception							Interactive Vehicle Reception
Autonomous Route Guidance										Personal Route Guidance									Vehicle Route Guidance
Dynamic Route Guidance								Basic Information Broadcast		Personal Basic Information Reception, Personal Route Guidance									Basic Vehicle Reception, Vehicle Route Guidance
ISP Based Route Guidance								Infrastructure Provided Route Selection, Interactive Infrastructure Info		Personal Interactive Information Reception, Personal Route Guidance									Interactive Vehicle Reception, Vehicle Route Guidance
Integrated Transportation Management/Route Guidance								Interactive Infrastructure Info, ISP Advanced Integrated Control Support								TMC Advanced Signal Control			Interactive Vehicle Reception, Vehicle Route Guidance
Yellow Pages and Reservation								Infrastructure Provided Yellow Pages & Reservation, Interactive Infrastructure Info		Personal Interactive Information Reception		Remote Interactive Information Reception							Interactive Vehicle Reception
Dynamic Ridesharing								Infrastructure Provided Dynamic Ridesharing, Interactive		Personal Interactive Information Reception		Remote Interactive Information Reception							Interactive Vehicle Reception

Table 2.3-1: Mapping Market Packages, Subsystems, and Equipment Packages

Market Packages	Commercial Vehicle Admin	Commercial Vehicle Check	Commercial Vehicle Subsys	Emergency Management	Emergency Vehicle Subsys	Emissions Management	Fleet and Freight Management	Information Service Provider	Parking Management	Personal Info Access	Planning Subsystem	Remote Traveler Support	Roadway Subsystem	Toll Administration	Toll Collection	Traffic Management	Transit Management	Transit Vehicle Subsystem	Vehicle
In Vehicle Signing													Roadway In-Vehicle Signing			TMC Input to In-Vehicle Signing			In-Vehicle Signing System
Vehicle Safety Monitoring																			Vehicle Safety Monitoring System
Driver Safety Monitoring																			Driver Safety Monitoring System
Longitudinal Safety Warning																			Vehicle Longitudinal Warning System
Lateral Safety Warning																			Vehicle Lateral Warning System
Intersection Safety Warning													Roadway Intersection Collision System			TMC Multi-Modal Coordination			Vehicle Intersection Collision Warning
Pre-Crash Restraint Deployment																			Vehicle Pre-Crash Safety Systems
Driver Visibility Improvement																			Driver Visibility Improvement System
Advanced Vehicle Longitudinal Control																			Vehicle Longitudinal Control
Advanced Vehicle Lateral Control																			Vehicle Lateral Control
Intersection Collision Avoidance													Roadway Intersection Collision System						Vehicle Intersection Control
Automated Highway System													Roadway Systems for AHS			TMC for AHS			Vehicle Systems for AHS
Fleet Administration			On-board Trip Monitoring				Fleet Administration, Fleet Maintenance Management	Infrastructure Provided Route Selection											
Freight Administration			On-board Cargo Monitoring				Freight Administration and Management												
Electronic Clearance	CV Information Exchange	Roadside Electronic Screening	On-board CV Electronic Data																
Electronic Clearance Enrollment	Credentials and Taxes Adminstration						Fleet Credentials and Taxes Management and Reporting												
International Border Electronic Clearance	CV Information Exchange, International CV Administration	International Border Crossing	On-board CV Electronic Data				Fleet Credentials and Taxes Management and Reporting												
Weigh-In-Motion		Roadside WIM	On-board CV Electronic Data																
Roadside CVO Safety	CV Information Exchange, CV Safety Adminstration	Citation and Accident Electronic Recording, Roadside Safety Inspection	On-board CV Electronic Data																
On-board CVO Safety	CV Information Exchange, CV Safety Adminstration	Citation and Accident Electronic Recording	On-board CV Safety																
CVO Fleet Maintenance			On-board CV Safety, On-board Trip Monitoring				Fleet Maintenance Management												
HAZMAT Managment			On-board Cargo Monitoring	Emergency and Incident Management Communications, Emergency Response Management, Emergency Mayday			Fleet HAZMAT Management												Vehicle Mayday I/F
Emergency Response				Emergency and Incident Management Communication, Emergency Response	On-board EV Incident Management Communication														
Emergency Routing				Emergency Vehicle Routing and communications	On-board Vehicle Signal Coordination			EM Route Plan Information Dissemination								TMC Multi-Modal Coordination			
Mayday Support				Emergency Mayday and E-911 I/F						Personal Mayday I/F		Remote Mayday I/F							Vehicle Mayday I/F
ITS Planning											Data Collection and ITS Planning								

Table 2.3-2: Market Package to User Service Relationships

		User Services																													
	Market Packages	1.1 - Pre - Trip Travel Information	1.2 - En - Route Driver Information	1.3 - Route Guidance	1.4 - Ride Matching And Reservation	1.5 - Traveler Services Information	1.6 - Traffic Control	1.7 - Incident Management	1.8 - Travel Demand Management	1.9 - Emissions Testing And Mitigation	1.10 Highway-Rail Intersection	2.1 - Public Transportation Management	2.2 - En - Route Transit Information	2.3 - Personalized Public Transit	2.4 - Public Travel Security	3.1 - Electronic Payment Services	4.1 - Commercial Vehicle Electronic Clearance	4.2 - Automated Roadside Safety Inspection	4.3 - On - Board Safety Monitoring	4.4 - Commercial Vehicle Administrative Process	4.5 - Hazardous Material Incident Response	4.6 - Commercial Fleet Management	5.1 - Emergency Notification And Personal Security	5.2 - Emergency Vehicle Management	6.1 - Longitudinal Collision Avoidance	6.2 - Lateral Collision Avoidance	6.3 - Intersection Collision Avoidance	6.4 - Vision Enhancement For Crash Avoidance	6.5 - Safety Readiness	6.6 - Pre - Crash Restraint Deployment	6.7 - Automated Vehicle Operation
ATMS	Network Surveillance						✓																								
	Probe Surveillance						✓																								
	Surface Street Control						✓	✓																							
	Freeway Control						✓	✓	✓																						
	HOV and Reversible Lane Management						✓		✓																						
	Traffic Information Dissemination						✓				✓																				
	Regional Traffic Control						✓																								
	Incident Management System							✓																							
	Traffic Network Performance Evaluation						✓		✓																						
	Dynamic Toll/Parking Fee Management								✓							✓															
	Emissions and Environmental Hazards Sensing									✓																					
	Virtual TMC and Smart Probe Data		✓				✓	✓																							
	Standard Railroad Grade Crossing										✓																				
	Advanced Railroad Grade Crossing										✓																				
	Railroad Operations Coordination										✓																				
APTS	Transit Vehicle Tracking											✓	✓	✓	✓																
	Transit Fixed-Route Operations											✓	✓																		
	Demand Response Transit Operations											✓	✓	✓																	
	Transit Passenger and Fare Management												✓			✓															
	Transit Security											✓			✓																
	Transit Maintenance											✓																			
	Multi-modal Coordination						✓		✓			✓																			
ATIS	Broadcast Traveler Information	✓	✓										✓																		
	Interactive Traveler Information	✓	✓										✓	✓		✓															
	Autonomous Route Guidance		✓	✓																											
	Dynamic Route Guidance		✓	✓																											
	ISP Based Route Guidance	✓	✓	✓												✓															
	Integrated Transportation Mgmt/Route Guidance		✓	✓												✓															
	Yellow Pages and Reservation	✓	✓			✓										✓															
	Dynamic Ridesharing	✓	✓		✓								✓	✓		✓															
	In Vehicle Signing		✓				✓				✓																				
AVSS	Vehicle Safety Monitoring																												✓	✓	
	Driver Safety Monitoring																												✓		
	Longitudinal Safety Warning																								✓				✓		
	Lateral Safety Warning																									✓			✓		
	Intersection Safety Warning										✓																✓		✓		
	Pre-Crash Restraint Deployment																												✓	✓	
	Driver Visibility Improvement																											✓			
	Advanced Vehicle Longitudinal Control																								✓						
	Advanced Vehicle Lateral Control																									✓					
	Intersection Collision Avoidance										✓																✓				
	Automated Highway System																														✓
CVO	Fleet Administration																					✓									
	Freight Administration																				✓										
	Electronic Clearance																✓			✓											
	CV Administrative Processes																✓			✓											
	International Border Electronic Clearance																✓			✓											
	Weigh-In-Motion																✓														
	Roadside CVO Safety																	✓													
	On-board CVO Safety																		✓												
	CVO Fleet Maintenance																		✓			✓									
	HAZMAT Managment							✓													✓	✓									
EM	Emergency Response																							✓							
	Emergency Routing																							✓							
	Mayday Support																						✓	✓							
	ITS Planning											✓																			

2.4 Market Package Synergy

One of the unique attributes of the National Architecture Program is the breadth of ITS services that it covers. This scope allows each potential service to be considered in context with all other ITS services, identifying common features and shared functionality. Questions such as: “Once I implement electronic toll collection in my region, what other services can I implement by extending the beacon infrastructure?”, and “What sorts of efficiencies are possible when advanced traveler information and traffic management systems are implemented in the same region?” are readily answered through the National Architecture. These inter-relationships, or synergies, are presented for each of the defined market packages in this section.

Consideration for these market package synergies can result in more efficient deployment of ITS services over time. The architecture can only identify the potential synergies, it is up to the local implementor to develop a deployment strategy that capitalizes on these efficiencies.

Synergies have been identified and analyzed for each equipment package and then aggregated and presented in this section at the market package level. A large number of synergies can be derived from the Architecture Framework by examining the data flows that are shared between equipment packages. Only the most significant synergies are brought forward and discussed in this section.

Several different types of synergies have been identified, from most restrictive to least restrictive as follows.

> Interdependent: Interdependent equipment packages are the most closely coupled. Two equipment packages are interdependent if both must be deployed to achieve an ITS service. If interdependent equipment packages are not deployed at the same time in the same region, the resulting service will be marginal or non-existent. All interdependent equipment packages have been allocated to the same market package to reflect this required association. Since interdependent equipment packages are not allocated to different market packages, there are no interdependent relationships between market packages.
>
> Common Functions: Equipment packages which reside in the same subsystem can share common functions to more efficiently implement the required services. This type of synergy reflects the potential sharing of hardware and/or software to perform a function that is required by both equipment packages. The shared functions are included in only one of the equipment packages and synergy is noted between the equipment package which includes the common equipment and the remaining equipment package(s) which utilize it. Many equipment packages rely on equipment included in more basic equipment packages to support more advanced capabilities. Such "incremental" equipment packages allow efficient deployment over time by building on existing equipment capabilities. In other cases, equipment packages which share functionality are of the same relative

sophistication. In such cases, the dependent equipment packages may be implemented in either order based on the needs (and preferences) of the end user. The common equipment is purchased with the first equipment package to be deployed.

Shared Information: Some equipment packages rely on information provided by a equipment package in a separate subsystem. In many cases, if the equipment package which supplies the information is not deployed, the equipment package which relies on the information will still provide degraded capabilities but not satisfy all user service requirements allocated to it. Typically, this “Shared Information” synergy reflects information that is shared between an information collection/provider equipment package in the infrastructure and an information user equipment package which is part of a second infrastructure subsystem or a mobile subsystem.

Complementary: Even when equipment packages may be independently deployed and operated to achieve the required user services (i.e., the equipment packages are not part of the same market package, do not share equipment, and are not required to share information), there may still be synergy between the provided services which should be considered in an implementation strategy. Complementary equipment packages provide compatible services which, taken together, enhance net system performance. In most cases, this relationship reflects the sharing of optional information between equipment packages within the architecture definition. In such cases, the information generated by one equipment package, if available, enhances the service provided by a second equipment package. In contrast, a Shared Information dependency, if not satisfied, prevents the associated equipment packages from meeting all of the user service requirements.

A series of five diagrams and accompanying discussion describe the principal synergies identified for the market packages. In each diagram, the connections represent the synergies between the market packages. Tracing the diagrams along the flows provides various efficient deployment sequences that leverage the incremental nature of the market packages.

The connections are coded to represent the types of synergies between market packages. When market packages are related in more than one way, the most restrictive dependency type is shown. (e.g., If two market packages share common functions and share information, the flow connecting the two market packages would reflect a "Common Functions" synergy.). Note that the "Interdependent" relationship is not represented in the figure since this synergy exists only between equipment packages within the same market package.

Each of the diagrams illustrate the market package synergies for a particular stakeholder area (e.g., Traffic Management, Traveler Information, etc.) Often, synergies will cross stakeholder boundaries (e.g., Traveler Information market packages are often reliant on information from Traffic Management market packages). These synergies are documented by "off-page references" which indicate the stakeholder area in an oval along with the associated market package. The text accompanying each diagram briefly describes, and justifies, the major synergies.

Advanced Traffic Management Systems

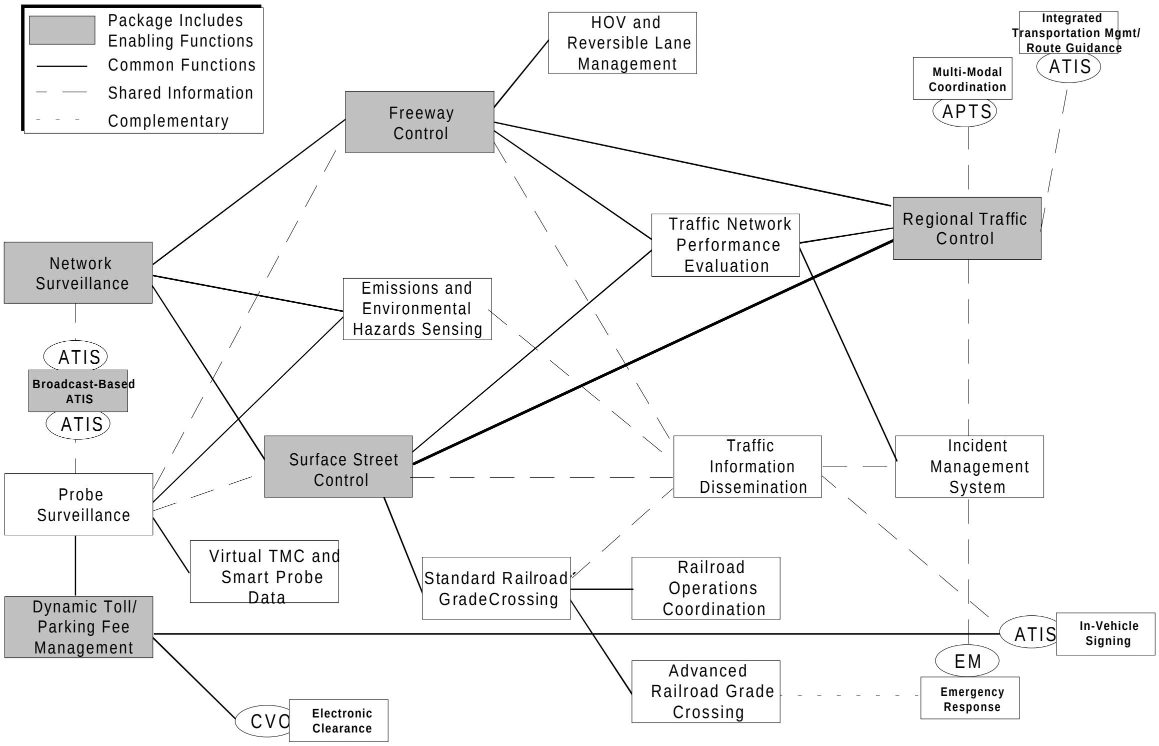


Figure 2.4-1. Advanced Traffic Management Systems Market Package Synergies.

The most significant common feature of the Traffic Management market packages is the shared need for traffic information. Each of these packages are supported by the basic surveillance infrastructure that is implemented through the two surveillance market packages. The information provided by this equipment (e.g., traffic counts and speeds) can be used for many purposes, including control and management of the traffic signals, incident management, emissions management, and traveler information. The surveillance data can also be saved as historical data for planning purposes or for evaluating the effectiveness of previous system enhancements. Each of the synergies that have been identified between the Traffic Management market packages are elaborated in the following descriptions.

Network Surveillance Market Package

This market package implements the basic roadside sensors, controllers, and communications infrastructure equipment which is leveraged by most of the other ATMS market packages. In addition to providing the information necessary to support more advanced traffic management implementations, this package also shares traffic information with the ATIS market packages.

Probe Surveillance Market Package

This market package provides an alternative approach to surveillance which provides many of the same fundamental benefits as the network surveillance market package. The dependency to the Surface Street and Freeway control market packages is denoted as data sharing since this package does not require implementation of the extensive distributed roadside infrastructure that may be directly utilized by the other ATMS packages. Dedicated Short Range Communications and AVI technologies may be shared between this package and the Dynamic Toll/Parking Management package. The Virtual TMC and Smart Probe Data market package adds additional “smart probe” capabilities such as road condition monitoring to the basic probe capabilities offered by this package.

Dynamic Toll/Parking Fee Management Market Package

This market package shares common functionality with the Electronic Clearance, In-Vehicle Signing, and Probe Surveillance market packages. Each of these market packages are additional potential applications for the dedicated short range communications, AVI, and rudimentary driver interface capabilities offered by this Toll/Parking market package.

Freeway Control Market Package

The infrastructure implemented to support this market package facilitates implementation of the HOV and Reversible Lane Management market package. HOV management should be able to utilize much of the same wireline communications, surveillance, and control infrastructure provided by this market package. Several more advanced traffic management market packages build on the fundamental infrastructure and control strategies supported by this package by increasing the level of coordination and/or increasing the sophistication of the control strategies.

Surface Street Control Market Package

This market package provides a basic surface street control building block, analogous to the Freeway Control Market Package above. The highway-highway intersection management capabilities provided by this market package are closely related to the highway-rail intersection capabilities provided by the market packages which support grade crossings.

Standard Railroad Grade Crossing Market Package

This market package manages traffic at highway-rail intersections using equipment that has potential commonality with equipment used for surface street control. The active warning systems and ancillary supporting equipment included in this market package provide the basic equipment that is augmented with additional features in the Advanced Railroad Grade Crossing market package. In the same way, the basic communications between Traffic Management and Rail Operations that is established in this market package is expanded and leveraged in the Rail Operations Coordination Market Package. The basic intersection status provided to the driver by this market package may be expanded and also provided through the Traffic Information Dissemination market package (e.g., variable message sign displays) and the In-Vehicle Signing market package. The communication of intersection status to the vehicle provided by the In-Vehicle Signing market package can be further extended and applied to intersection safety warning and intersection collision avoidance as will be seen in the analysis of the ATIS and AVSS market packages.

Advanced Railroad Grade Crossing Market Package

This market package adds additional surveillance, physical barriers, and enhanced driver information systems to the core equipment included in the Standard Railroad Grade Crossing. The surveillance capabilities can enable real-time detection and reporting of collisions which can speed Emergency Response.

Railroad Operations Coordination Market Package

This market package provides additional coordination between railroad operations and traffic operations by building on the same interface established for the Railroad Grade Crossing market packages. This market package provides area-wide, accurate forecasts of grade crossing closures that can be factored into regional control strategies provided by the Regional Traffic Control market package.

Emissions and Environmental Hazards Sensing Market Package

This market package provides emissions and hazards information to the Traffic Information Dissemination market package. It may be interconnected with the basic surveillance infrastructure deployed at the roadside for cost-effective implementation.

Traffic Information Dissemination Market Package

This market package provides basic roadside information dissemination infrastructure which is applicable to a wide variety of traffic management market packages. The basic infrastructure which provides an information dissemination interface located at the roadside which is controlled by the traffic management subsystem may be extended to provide in-vehicle signing capabilities in more advanced applications.

Incident Management System Market Package

This market package utilizes the traffic information dissemination and traffic control capabilities deployed through other market packages to adapt traveler information and traffic control strategies to account for incidents. The communications infrastructure and working relationships established to support Incident Management can also be used to support the coordination required for the regional traffic control market package. This market package shares information with the Emergency Response market package to enable coordination between traffic management and emergency management subsystems in incidents and other emergencies impacting traffic management strategies.

Regional Traffic Control Market Package

This market package enhances the coordination between traffic management systems within a region. It directly leverages the existing traffic control systems (freeway and arterial) already implemented in the region through improved coordination between traffic management systems in the region. It also benefits from the same coordination between agencies within the region that is established in the Incident Management System market package. The regional scope of this market package provides the opportunity to fully realize the benefits of enhanced coordination with the transit systems and railroads operating in the region.

Advanced Traveler Information Systems

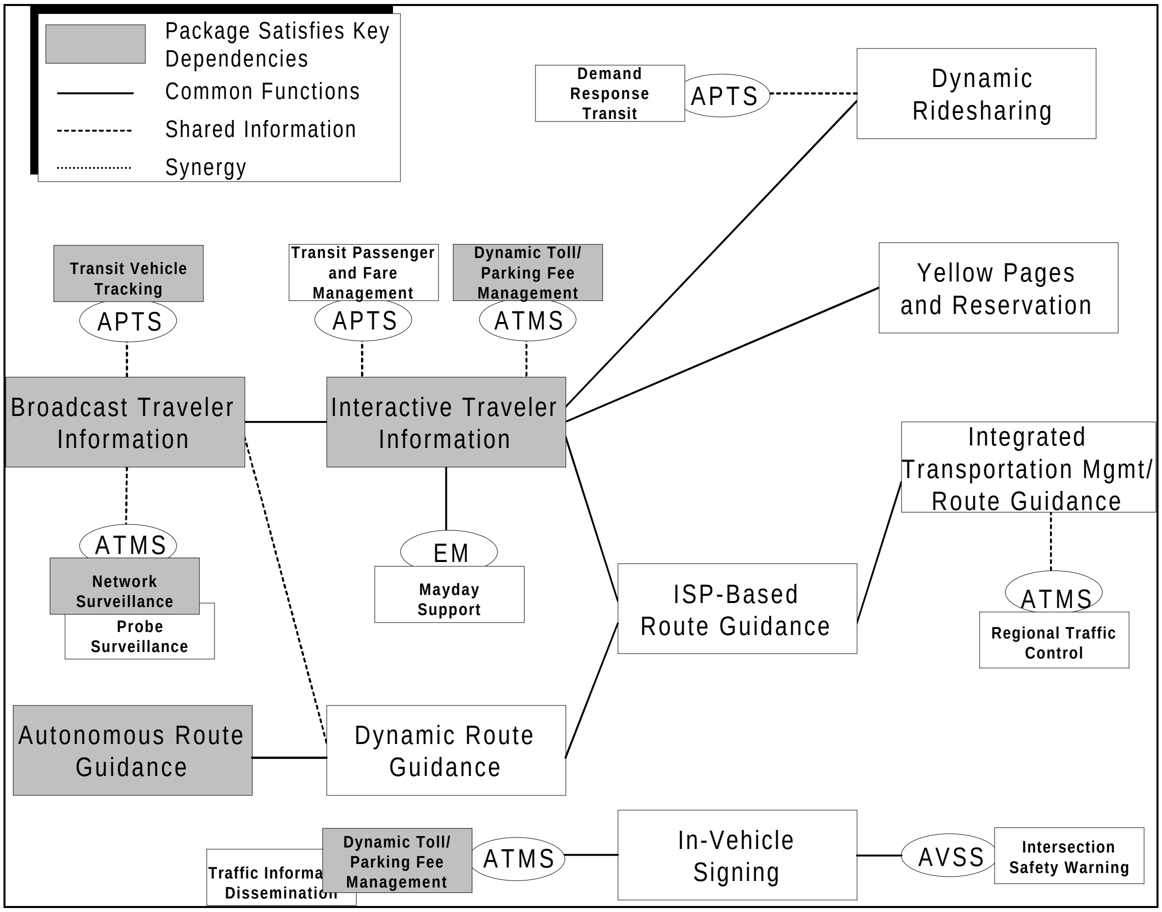


Figure 2.4-2. Advanced Traveler Information Services Market Package Synergies.

Broadcast Traveler Information Market Package

This market package shares many of the basic transportation data collection and management functions with more advanced interactive traveler information packages. This market package and its interactive counterparts each collect traffic, transit and other traveler information for processing and disseminating. In addition to providing advisories and other basic traffic information, this market package can be extended to provide real-time traffic information in a format supporting dynamic route guidance.

Interactive Traveler Information Market Package

This market package shares the basic traveler information collection and management and interactive communications capabilities with more advanced or specialized traveler information market packages. The basic interactive traveler information service can be extended to support centralized route planning services offered by the ISP-Based Route Guidance market package. The interactive capabilities of this market package allow it to better use information provided by the Transit Passenger and Fare Management and the Dynamic Toll/Parking Fee Management market packages for transit, toll, and parking fees and transit schedules and parking occupancy and reservation.

Autonomous Route Guidance Market Package

This market package provides a rich set of in-vehicle functions that can be utilized by enhanced route guidance services that require interaction with the infrastructure. Each of the more advanced route guidance market packages provide successive enhancements to the infrastructures role in supporting the autonomous vehicle equipment included in this market package.

In-Vehicle Signing Market Package

This market package communicates between the vehicle and roadside using the same dedicated short-range communications used by the Dynamic Toll/Parking Fee Management market package. The infrastructure in the Traffic Information Dissemination market package which provides dynamic driver advisories to roadside variable message signs may be extended to support provision of information to the vehicle for in-vehicle display. The communications of road status to the vehicle for in-vehicle display provides a incremental step towards more advanced intersection safety warning and collision avoidance implementations.

Advanced Public Transit Systems

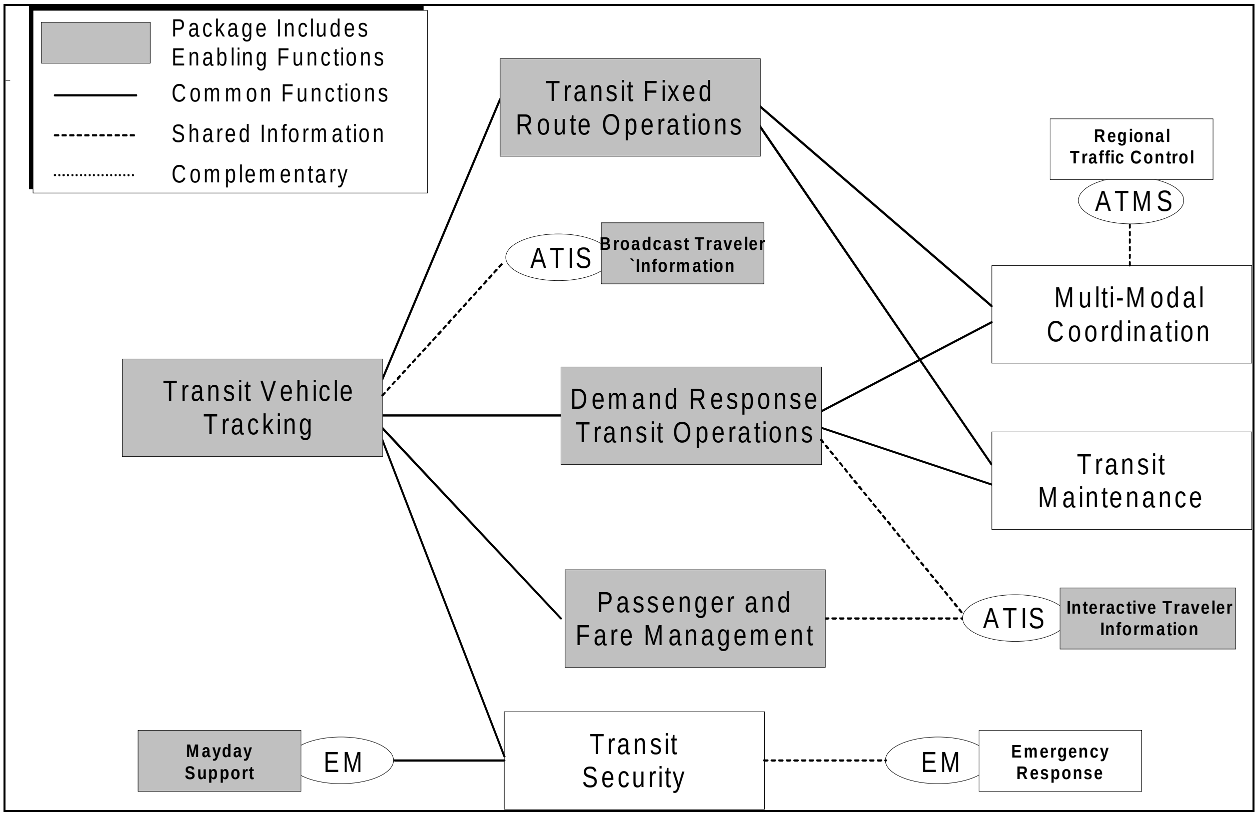


Figure 2.4-3. Advanced Public Transit Systems Market Package Synergies.

Transit Vehicle Tracking Market Package

This market package provides a fundamental vehicle location service that is required by many of the other APTS related market packages since accurate and current knowledge of transit vehicle position is key to many other services. The automated vehicle location and tracking capability provided by this market package is necessary to support the advanced operations packages, passenger and fare management, and transit security. Current transit schedule information, derived through this package, also supports the traveler information market packages.

Transit Fixed Route and Demand Response Transit Operations Market Packages

These two market packages support operations and dispatch and provide key database management functions which are utilized to support more specialized Transit Maintenance and Multi-Modal Coordination market packages. The Demand Response Transit service is only well supported by the more advanced interactive traveler information services which enable a convenient, real-time request/response interface to travelers seeking transit.

Transit Security Market Package

This market package shares emergency notification and status information with the Emergency Response market package. It provides many of the same safety features that are provided by the Mayday Support market package which is oriented towards individual subscribers rather than a transit provider.

Passenger and Fare Management Market Package

This market package shares information with the Interactive ATIS Driver and Traveler Information market package for providing real-time fare information to prospective transit passengers.

Multi-Modal Coordination Market Package

This market package shares transit signal request information with the Regional Traffic Control market package.

Commercial Vehicle Operations

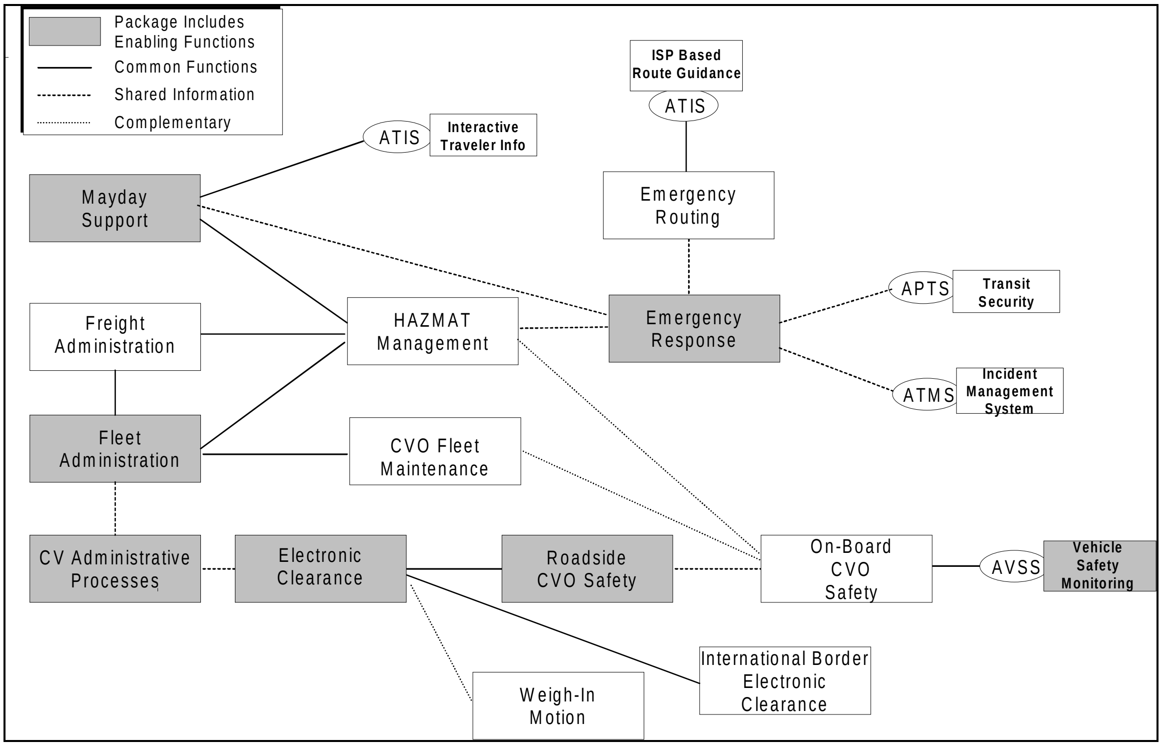


Figure 2.4-4. Commercial Vehicle Operations and Emergency Management Market Package Synergies.

Fleet Administration Market Package

This market package shares common tracking, management, and dispatch capabilities with the Freight Administration, CVO Fleet Maintenance, and HAZMAT Management market packages.

Freight Administration Market Package

This market package adds more specific freight monitoring capabilities to the basic tracking capabilities provided by fleet administration. These more advanced cargo tracking capabilities also support the HAZMAT Management market package.

CV Administrative Processes

This market package enables the Electronic Clearance market package since participants must both enroll (through this package) and be cleared electronically (through the Electronic Clearance market package) before a service is actually provided to participating carriers. As well, this market package supports various one-stop shopping applications which facilitate and expedite the administration of commercial vehicles.

Electronic Clearance

The International Clearance market package extends the basic clearance functions provided by the Electronic Clearance package by adding an interface to customs and permitting to support entry and exit from Canada and Mexico. The Weigh-In-Motion market package provides a logical enhancement to the AVI and commercial vehicle screening capabilities offered by this package. The Roadside CVO Safety Market Package provides another potential enhancement that enlists the basic AVI functions established for Electronic Clearance.

Roadside and On-Board CVO Safety Market Packages

This On-Board CVO Safety market package provides advanced sensory and diagnostic capabilities on-board the vehicle that complements the services provided by the HAZMAT Management, CVO Fleet Maintenance, and Roadside CVO Safety market packages by making additional diagnostic data. The roadside checking and verification against database entries and safety standards provided by the Roadside market package will be enhanced by the on-board safety verification provided by the CVO On-Board Safety market package.

HAZMAT Management Market Package

This market package provides HAZMAT spill notification information to the Emergency Response market package.

Emergency Management

Mayday Support

The Mayday Support market package requires a portable traveler interface and interactive, wide area wireless communications between the traveler and the infrastructure. This same portable traveler interface and interactive communications capabilities can be leveraged to support other traveler information capabilities addressed by the Interactive Traveler Information market package. This progression reflects a likely scenario in which the consumer is motivated by the potential for enhanced safety, installs the equipment, and then becomes part of a larger market for more advanced interactive information services.

Emergency Response Market Package

The Emergency Response market package enables a rapid response to the emergency notifications provided by the Mayday Support, Transit Security, and Incident Management System market packages. The Emergency Routing Market Package provides the basic dispatcher support capabilities which may be extended and integrated to support the required multi-agency coordination supported by the Emergency Response Market Package.

Emergency Routing Market Package

The emergency routing capabilities supported by this market package are a special application of similar route selection algorithms and processing capabilities provided by the traveler-oriented ISP Based Route Guidance Market Package.

Advanced Vehicle Safety Systems

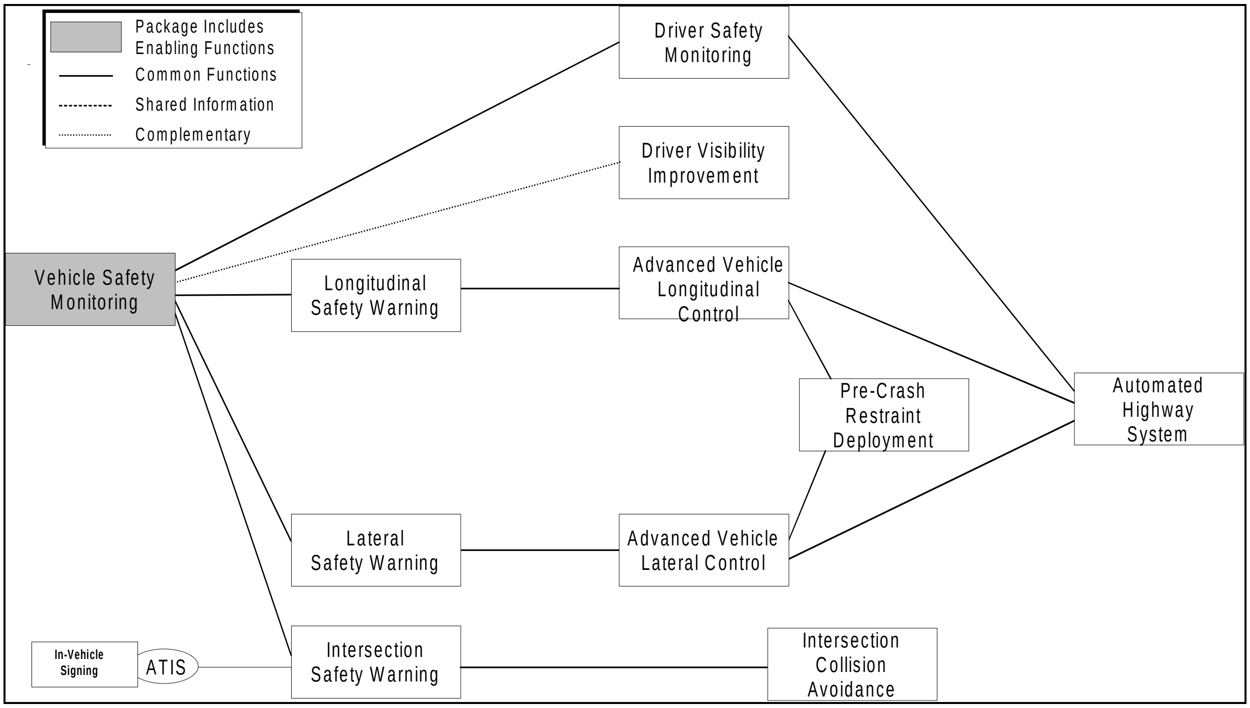


Figure 2.4-5. Advanced Vehicle Safety Systems Market Package Synergies.

Vehicle Safety Monitoring Market Package

> This market package shares common functions with the Driver Safety Monitoring, Longitudinal Safety Warning, Lateral Safety Warning and Intersection Safety Warning market packages since each of these packages includes common sensory, processing, and driver interface capabilities. Each of these safety-related market packages may include separate sensing devices, however similar processing algorithms as well as the same or similar processors can be expected. The status and warning displays can be expected to be similar as well.

Longitudinal Safety Warning Market Package

> This market package shares common sensory functions with the Advanced Vehicle Longitudinal Control market package. The sensing and detecting of obstacles in the longitudinal direction performed in this market package is directly applicable to the Advanced Vehicle Longitudinal Control market package.

Lateral Safety Warning Market Package

> This market package shares common functions with the Advanced Vehicle Lateral Control market package. The proximity sensing and lane following functions

performed in this market package may be applied to the Advanced Vehicle Lateral Control market package.

Intersection Safety Warning Market Package

This market package has common functions with the Intersection Collision Avoidance market package. The sensing and detecting of obstacles and conditions in the vicinity of an intersection and communicating this information to on-coming vehicles performed in this market package is directly applicable to its successor, the Intersection Collision Avoidance market package. The provision of basic intersection status to the vehicle supports intersection safety warning and is a logical extension of the in-vehicle signing function provided by a separate market package.

Advanced Vehicle Longitudinal and Lateral Control Market Packages

These two market packages share common functions with the Pre-Crash Restraint Deployment and Automated Highway System market packages. The capability to sense, detect, and act based upon longitudinal and lateral detection is a requirement for the Pre-Crash Restraint Deployment market package. This market package provides these functionalities that would be integral to the Pre-Crash Restraint Deployment market package. Complete automated control of the vehicle is an extension to these predecessor packages.

2.5 Technology Requirements

A range of technologies, each with unique performance, cost, and maturity characteristics can be used to implement ITS. The majority of these technologies are commercially available and expose the implementor to little technical risk. The most problematic technology implications exist where a required ITS function is not supported by any cost-effective, commercially available technology.

In a few cases, required technologies may not exist or may be too costly and/or unreliable for commercial application. Market packages that are dependent on such technologies require further research and development to provide the enabling technology and integrate it into a commercially viable deployment package. This paragraph identifies the technologies associated with the market packages, defines and determines the maturity for each technology area, and postulates the potential impact to deployment for those critical technologies requiring additional research and development.

Table 2.5-1 identifies functional groups of technologies and relates them to the market packages. Each column in the table represents a general technology area which is applied through one or more market packages to support ITS user services. The technology requirements for each market package are presented in the body of the table using the following icons:

> ■: The opaque (black) squares denote a basic relationship between the market package and the technology area. This assignment indicates that the technology area is fundamental to the core services provided by the market package.
>
> ❑: The transparent (white or gray) squares denote a secondary relationship between the market package and the technology area. This assignment indicates that the technology would enhance the market package through provision of optional features or by playing a supplementary role in supporting core services. Use of this technology area is desirable but not necessarily required for market package implementation.

The columns in Table 2.5-1 are highlighted for technology areas that require further development. The rows in the table are highlighted where a market package requires at least one of these critical technology areas.

Table 2.5-1: Market Package Requirements by Technology Area

		Technology Area																							
		Sensor										Comm								User I/F			Control		
	Market Packages	Traffic	Vehicle Status	Environment	Vehicle Monitoring	Driver Monitoring	Cargo Monitoring	Obstacle Ranging	Lane Tracking	Security	Location Determination	Cell-Based (U1t)	Vehicle-Roadside (U2)	Vehicle-Vehicle (U3)	Broadcast (U1b)	Fixed (W)	Algorithms	Information Mgmt	Payment	Driver	Traveler	Operator	Signals	Signs	Vehicle
A T M S	Network Surveillance	■		❑												■	❑	■				■			
	Probe Surveillance				■						■	■	❑			❑	■	■				■			
	Surface Street Control	■														■						■	■		
	Freeway Control	■														■						■	■	❑	
	HOV and Reversible Lane Mgmt	■	■								■	■				■	❑					■	❑	■	
	Traffic Information Dissemination														■	■	❑	■				■		❑	
	Regional Traffic Control	■			■											■	■	■				■	■	■	
	Incident Management System	■			■						■	■				■	■	■				■	❑	❑	
	Traffic Network Performance Eval	■			■											❑	■	■				■			
	Dynamic Toll/Parking Fee Mgmt	■	■									❑	■		❑	■	■	■	■	■		■	❑	❑	
	Emissions and Environmental Haz.		■	■	❑											■	■	■		❑		■		❑	
	Virtual TMC and Smart Probes				■						■	■	❑			❑	■	■				■			
	Standard Railroad Grade Crossing	■														■		❑					■		
	Advanced Railroad Grade Crossing	■	❑			❑		❑								■	■	❑					■		
	Railroad Operations Coordination				■						■	■	❑			■	■	■				■			
A P T S	Transit Vehicle Tracking				❑	❑					■	■	❑			❑		■			❑	■			
	Transit Fixed-Route Operations											❑	❑			❑		■		❑	❑	■			
	Demand Response Operations											■				❑	❑	■		■	❑	■			
	Transit Passenger and Fare Mgmt									❑	❑	❑				❑		■	■		■	■			
	Transit Security									■	❑	❑				❑		❑		■	■	■			
	Transit Maintenance				■	❑					❑	❑				❑		■		■		■			
	Multi-modal Coordination										■	■	■			■	❑	■		■		■			
A T I S	Broadcast Traveler Information	■		❑											■	■	■	❑		■	■	■			
	Interactive Traveler Information	■		❑							❑	■				■	■	❑		■	■	■			
	Autonomous Route Guidance										■						■	❑		■	■				
	Dynamic Route Guidance	■		❑							■	❑			■	■	■	❑		■	■				
	ISP-Based Route Guidance	■		❑							■	■				■	■	■	❑	■	■	■			
	Integrated Transportation Mgmt/RG	■		❑							■	■				■	■	■	❑	■	■	■			
	Yellow Pages & Reservation										❑	■				■	■	❑		■	■	■			
	Dynamic Ridesharing									❑		■				■				■	■	■			
	In Vehicle Signing		❑	❑	❑	❑	❑				■	❑	■			❑	❑	❑		■		❑			
A V S S	Vehicle Safety Monitoring				■							❑					❑			■					
	Driver Safety Monitoring				■	■						❑					■			■					
	Longitudinal Safety Warning				■	❑		■									■			■					
	Lateral Safety Warning				■	❑		■	■								■			■					
	Intersection Safety Warning		■	❑	■	❑		■	■			❑	■	❑		■	■	❑		■			❑	❑	
	Pre-Crash Restraint Deployment				■	❑		■									■								❑
	Driver Visibility Improvement					❑		■												■					
	Advanced Vehicle Longitudinal Ctrl				■	❑		■									■			■					■
	Advanced Vehicle Lateral Control				■	❑		■	■								■			■					■
	Intersection Collision Avoidance		■	❑	■	■		■	■			❑	■	❑		■	■	❑		■			❑	❑	■
	Automated Highway System	❑	■	❑	■	■		■	■	❑	■	■	■	■		■	■	■	❑	■		■	❑	❑	■
C V O	Fleet Administration				■						■	■	❑			❑	❑	■		■		■			
	Freight Administration						■				■	■	❑			■	❑	■		■		■			
	Electronic Clearance												■			■		■		■		■	❑	❑	
	CV Administrative Processes											❑				■		■							
	International Border Clearance												■			■		■		■		■	❑	❑	
	Weigh-In-Motion		■										❑				❑					■	❑	❑	
	Roadside CVO Safety		■		❑		❑						■			■	❑					■	❑	❑	
	On-board CVO Safety				■	■	■					❑	❑				❑			■					
	CVO Fleet Maintenance				■						■	■				❑	❑	■		■		■			
	Hazmat Management						■				■	■	❑			■	❑	■		■		■			
E M	Emergency Response									■	❑	❑				■	❑	■				■			
	Emergency Routing				❑	❑					■	■	❑			❑	❑	■		■		■			
	Mayday Support		❑								■	■				■		❑		■	■	■			
	ITS Planning													■		■		■				■			

Table 2.5-2 defines the ITS-relevant technologies identified in Table 2.5-1 and highlights those areas which have been defined as critical. In the table, each basic technology area is defined and qualitatively assessed with regard to relative maturity. The maturity assignments used in the table are defined as follows:

- **Mature:** Current commercially available technology supports the identified ITS requirements in this area. Deployment of the ITS user services is not predicated on further research and development of these technologies.

- **Mature with rapid innovation:** Current commercially available technology supports the identified ITS requirements. The area is one of rapid technology growth which indicates that the basic support provided by current technologies will likely be superseded within the deployment period. While further research and development is not required to support ITS, future deployments may benefit from technology enhancements which should not be precluded by excessive rigidity in the architecture or deployment definitions.

- **Mixed:** This technology area satisfies a range of ITS requirements including some that are not supported by current technology. Useful services may be deployed using currently available technologies; however, satisfying all user service requirements will require additional research and development to bolster the identified deficiencies. Where this assignment is made, the associated description in Table 2.5-1 highlights the specific areas where technology advancement is required.

- **Immature:** Additional research and development is required before technologies in this area can be cost-effectively and reliably applied to support ITS services. In some cases, potentially suitable technologies have been applied in defense or aerospace applications. Additional research and development is still required in these areas to address the unique producibility, safety, and cost issues associated with larger commercial markets.

Technology areas identified as "Mixed" or Immature" are highlighted in Table 2.5-2 and considered further as "pacing technologies" in this analysis.

Few absolute conclusions can be drawn from the technology maturity assessment alone. The identification of a technology area as immature is not the same as an absolute prediction that deployments will not occur without significant further research. There are numerous examples where relatively immature technologies have been applied in successful products, depending on the customer’s needs and expectations. Voice recognition is an example of a technology that might be labeled as immature by this analysis and yet one already finds many workable voice recognition products on the market. Where the need is great enough, creative providers will find other approaches that can be used for interim deployments. For example, technologies which automate vehicle occupant sensing for purposes of determining compliance with HOV requirements are in their infancy. Special rules and manned surveillance stations with high speed cameras are being used in the Fast-Trac Tollway in Southern California to support vehicle occupant sensing today.

Although the relationship is not absolute, the deployment timing for the dependent market packages will be influenced by the timing of the required technology advancements. Unfortunately, accurately forecasting technology development timing is extremely difficult. This timing is dependent upon the current status of the required technology and the quantity and productivity of the research that will be performed in the area. Despite the difficulties, many forecasts of technology development timing have been made based on assessment of the best available information. Table 2.5-3 draws on the assessments contained in the National Program Plan, augmented by other sources, for each pacing technology area.

Table 2.5-2: ITS Technology Areas

Technology	Description	Maturity
Traffic Sensors	Sensor technology which monitors overall traffic conditions. Enables collection of basic aggregate measures such as occupancy, volume, and speed.	Mature
Vehicle Status Sensors	Sensors which determine individual characteristics of passing vehicles. Technologies which assess individual vehicle length, weight, number of axles, lane position, and speed are available. Enforcement application technologies that monitor emissions, passenger counts, and operational status for specific vehicles are less mature.	Mixed
Environment Sensors	Sensor technology which monitors local climate (temperature, humidity, precipitation, wind, pollution) and road surface status (dry, wet, ice, snow).	Mature
Vehicle Monitoring Sensors	The range of on-board sensor technologies which monitor vehicle condition (e.g. engine, brake, tire, and suspension status) and performance (current speed, acceleration, yaw, traction, current steering, throttle, braking, and transmission status).	Mature
Driver Monitoring Sensors	Technologies which monitor driver condition by monitoring driving characteristics and/or other psychophysiological symptoms associated with impaired performance.	Immature
Cargo Monitoring Sensors	Technologies which monitor various indicators of cargo status. Load distribution, temperature, acceleration, and pressure are among potential indicators that may be monitored depending on the nature of the cargo.	Mature
Obstacle Ranging Sensors	Technologies which detect and characterize potential obstacles (other vehicles, people, road debris) in a vehicle's vicinity. Supports family of applications with variable performance requirements. Advanced headway maintenance requires high frequency and precision. Driver warning systems may have reduced requirements due to human time scale. Vision enhancement sensors must support overall environment imaging.	Immature
Lane Tracking Sensors	Technologies on-board the vehicle which monitor the position of the vehicle with respect to the travel lane and optionally support interpretation of travel lane geometry ahead of the vehicle.	Immature
Security Sensors	Technologies which provide surveillance of, and restrict access to, secure public areas. Card readers which restrict access and closed circuit television cameras are examples.	Mature
Location Determination	Technologies which determine absolute position. Examples include GPS and other systems which apply trilateration to known locations, either terrestrial or space based. Augmenting these technologies are those which measure travel path and distance (e.g., odometer, compass, gyroscope) from a known location. Very high-precision systems associated with vehicle control applications are one remaining research area.	Mature w/ rapid innovation
Cell-Based Communication (U1t)	Two-way wide-area wireless communications. Primary examples of mature systems for transmitting ITS information include circuit-switched cellular, Cellular Digital Packet Data (CDPD), and Enhanced Specialized Mobile Radio. Future, emerging technologies include Personal Communications Services (PCS) and various Satellite Communications Networks.	Mature w/ rapid innovation

Table 2.5-2: ITS Technology Areas (continued)

Technology	Description	Maturity
Broadcast Communication (U1b)	Primary examples include alternative FM Subcarrier technologies. Low data rate RBDS is already standardized with initial market penetration. Multiple high data rate approaches (HSDS, STIC, and DARC) are being considered for standardization.	Mature w/ rapid innovation
Vehicle-Roadside Communication (U2)	Short range wireless communications between infrastructure and vehicle using active radio frequency, passive (backscatter) radio frequency, and/or infrared.	Mature w/ rapid innovation
Vehicle-Vehicle Communication (U3)	High data rate, short range, reliable two way digital communications between vehicles using RF, microwave or infrared spectrum. Favored technical approach has not been selected.	Immature
Fixed Communication (W)	Technologies used to carry information between fixed locations; technology choices are largely dependent on local service provider or local preference for private networks. Various networks (PSTN, ISDN, IP, PDN, private local network) support ITS requirements.	Mature w/ rapid innovation
Algorithms	Processing technology and advanced algorithms which enable advanced vehicle and traffic control applications. Overlap exists between this computational element and the other technology areas it supports.	Mixed
Information Management	Information storage, fusion, and retrieval systems supporting access to distributed heterogeneous data.	Mature w/ rapid innovation
Payment	Technologies which enable secure automated financial transactions in conjunction with information management and communications technologies above. Magnetic strip cards and Smart Card technologies are examples. Both contact and contactless technologies may be used.	Mature w/ rapid innovation
Driver Interface	Audio, visual, and tactile interface technologies appropriate for interaction with drivers during vehicle operation. Console displays (LED, LCD, etc.), heads-up displays and synthesized speech are primary examples of mature technologies. Technologies enabling voice input and non-distracting visual enhancement of the driver's view are less mature.	Mature w/ rapid innovation
Traveler Interface	Same technologies as for driver interface with other, varied constraints. Extreme portability requirements restrict interface options for hand-held devices. Additional capabilities, including hard copy options, for fixed presentation devices.	Mature
Operator Interface	Same as for traveler interface.	Mature
Signals	Control signals, barriers, or other physical control devices and supporting electronics.	Mature
Signs	Variable message signs including those which include interface to vehicle-roadside communications technologies enabling complementary in-vehicle displays.	Mature
Vehicle Control	Vehicle control system actuators and supporting processing technologies	Immature

Table 2.5-3: Pacing Technology Development Forecasts

Technology	Current Status	Research Projections	Delay
Vehicle Status Sensors -Emissions -Pass. Counts -Operational Status	Infrared technology commercially available to support remote sensing of CO and Hydrocarbons. On-going research in application to remote NOx sensing. Technologies which remotely count passengers without vehicle cooperation in infancy. Each of these sensor technologies can also contribute to an assessment of stationary vehicle operational status. Implementations which rely on vehicle reporting face fewer technical challenges but face similar institutional obstacles.	Uncertain market potential suggests research will primarily be funded by the public sector	Moderate - Long
Driver Monitoring Sensors	Research stage. Tests indicate marginal performance (75% detection rate with 3% false alarm rate cited in National Program Plan) for current implementations. New monitoring algorithms, monitoring of new symptoms, and combinational approaches are under research.	Uncertain market potential suggests research will primarily be funded by the public sector	Long Term
Obstacle Ranging Sensors	Preliminary commercial market initiatives. Ultrasonic, radar, and machine vision technologies have been developed and marketed in heavy vehicle proximity detection systems. Additional research required to extend performance/reliability to satisfy preemptive control app.'s and decrease cost to achieve private vehicle market price points.	Large market potential indicates continued robust private sector research initiatives, supplemented by federal research driven by safety benefits and AHS program.	Moderate
Lane Tracking Sensors	Research stage. Proof-of-concept systems using various infrastructure support concepts (e.g., magnetic nails, special paint/markers, active beacons) have been developed with promising results in controlled environments. Machine vision application to lane departure warning systems without special infrastructure support under study.	Potentially large market in the long term indicates continued private sector research initiatives, supplemented by federal research driven by safety benefits and AHS program.	Long Term
Vehicle-Vehicle Comm (U3)	Preliminary research stage. Academic research supported by isolated tests in US (PATH program), Japan (Toyota), and Europe (RACE Programme).	Near-term US research will continue on limited scale substantially augmented by AHS program in the near term.	Long Term
Algorithms	Varied status depending on application area (see other entries in this table). Traffic prediction algorithms (not covered elsewhere) are rudimentary since sufficient source data is not commonly available.	Level of research dependent on application area.	Moderate - Long
Vehicle Control	Academic research as well as proof-of-concept tests in US, Japan, and Europe funded by public sector and automotive industry. Sensory support and control algorithms are primary research areas.	Potentially large market suggests continued private sector research initiatives, supplemented by federal research driven by safety benefits and AHS program.	Moderate - Long

2.5.1 The Telecommunications Infrastructure and ITS Communications

Many of the technologies described in table 2.5-2 are identified as “Mature with rapid innovation”. Of these technology areas, perhaps none is more crucial to the initial success and continued viability of ITS than telecommunications. This section focuses on these existing telecommunications technologies and ventures to make a general projection of where “rapid innovation” will take these critical technologies in the future.

Over the last two decades, a massive telecommunication infrastructure has evolved, both for wired and wireless communication. The reliability and capacity of wireline networks has increased exponentially, enabling a wide array of new services and capabilities. As performance has increased, prices of most wireline telecommunication services have dropped remarkably. At the same time, the wireless communications consumer market was born and has since witnessed unprecedented growth. As an example, roughly $20 billion has been invested in the cellular infrastructure until 1995. The wireless industry, in its varied incarnations, now holds tremendous promise for the future, as evidenced by the fierce competition for its spectrum and the value attached to it. In fact, wireless’s predicted growth may alter many of the traditional paradigms of communication. Today, wireline and wireless networks can take various forms, public and private, as depicted conceptually in Figure 2.5-1.

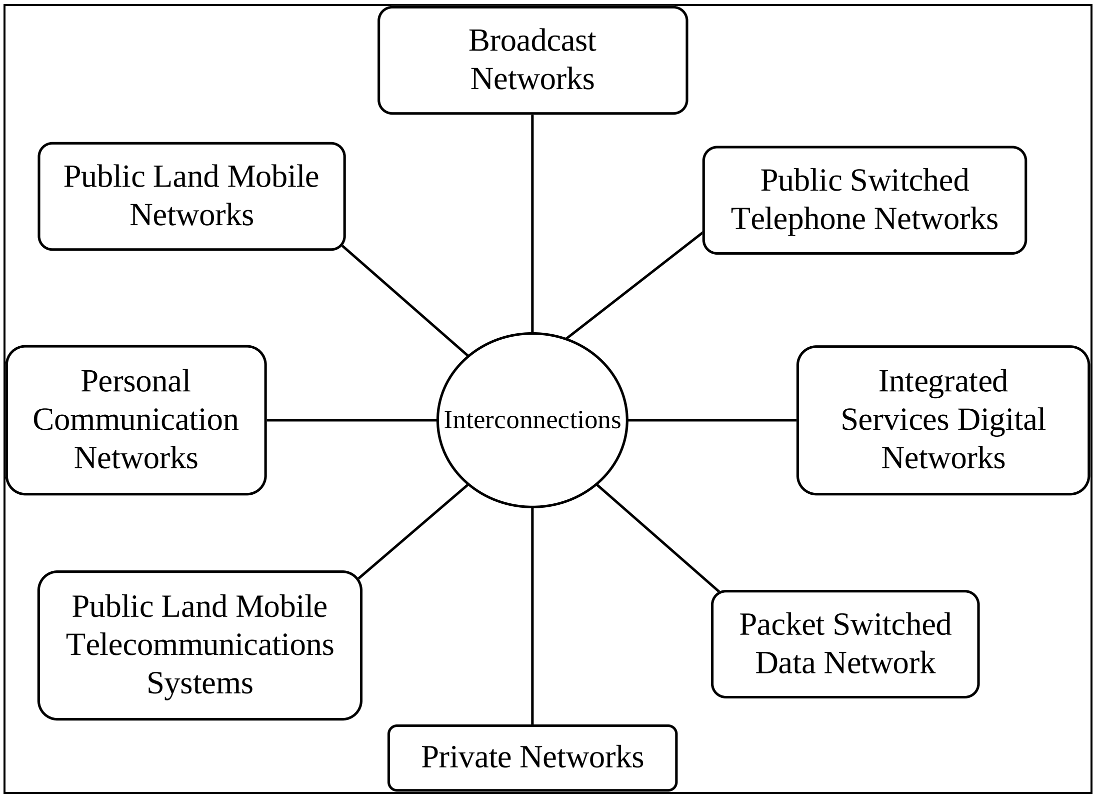


Figure 2.5-1 Overview of the Telecommunications Arena

Over the next twenty years, many new communication technologies and techniques, from multiple access to transport to switching, will be introduced at a rapid pace to support the demands of our information age. Presently available and emerging technologies will offer extensive opportunities to handle many ITS user services. The technology projections depicted in Table 2.5-4 identify the predicted availability of various communication technologies and infrastructures that could be exploited.

The natural competitive evolution of wireline and wireless infrastructures will yield communication systems that will:

1. Support communication services which include: voice (speech), data, image, video, and signaling.
2. Accommodate a wide variety of terminals, i.e., fixed, portable mobile, and in-vehicle mobile.
3. Preserve upward/downward terminal compatibility.
4. Allow mobile and fixed users to utilize the services regardless of geographical location (i.e., seamless communication).
5. Provide service flexibility, so that any combination of services may be used.
6. Make efficient and economical use of the spectrum.
7. Provide user authentication and billing functions.
8. Provide varied degrees of network security that preserve user privacy.
9. Have modular structures which will allow the systems to start from small and simple configurations then grow as needed in size and complexity.
10. Use, in many cases, open architectures which will permit the easy introduction of technology advancement and support of new applications.

As a reflection of the very desirable attributes delineated above, one of the fundamental guiding philosophies in developing the National ITS Architecture has been to leverage, to the extent possible, the existing and emerging telecommunication infrastructures. Doing so not only benefits ITS from the tremendous financial investment in the deployed and planned infrastructures, but also from the large time and effort expended in developing standards to allow interoperability and interconnectivity among disparate systems. Moreover, this enables the ITS users to share many of the scarce and valuable resources, and distribute their cost over a significantly broader population.

By embracing the heritage of the broad telecommunications industry, the cornerstone of whose success has been fulfilling users’ needs and meeting with their acceptance, ITS will be on the proper path towards a wide scale presence. This approach is essential to maximizing the feasibility of the architecture, and to mitigate the risk inherent in creating and offering intelligent transportation systems, services, and products, all of which are quite new.

Table 2.5-4 Communications Technology Projections for the Next 15 Years

Technologies	1992	1997	2002	2012
Wireless Access	FDMA Analog	FDMA and TDMA/CDMA Digital	CDMA/TDMA Digital	Mainly CDMA Digital
Wireless Capacity	Moderate	High (3-5x AMPS)	High (5-10x AMPS)	High (10-15x AMPS)
Wireless Signal Coverage	All Urban, Most Inter-Urban, Some Rural	All Urban and Inter-Urban, Most Rural	All Urban and Inter-Urban All inhabited Rural	Ubiquitous
Wireless Media				Transparent, Hybrid Terrestrial Satellite
• Terrestrial:	Most Macro	Full Macro, Initial Micro	Full Macro, Most Micro	Integrated Macro/Micro
• Satellite:	Limited GEO	Some GEO, Initial LEO	Full GEO, Partial LEO	Full GEO/ Full LEO
Wireline Availability	Widespread Copper Limited Fiber for LAN's and Backbone	Fiber Backbone with Copper Drops Very Limited Hybrid Fiber-Coax	Limited Fiber to Curb Some Hybrid Fiber-Coax	Partial Fiber to Curb Limited Fiber to Home
Transfer Mode	Full Circuit-Switching Packet-Switching Initial Frame-Relaying	Partial Frame-Relaying Very Limited Asynchronous Transfer Mode (ATM)	Most Frame-Relaying Initial Fast-Packet Switching Partial ATM	Most Fast-Packet Switching Most ATM
Data Protocol	X.25, X.21	Frame-Relay ATM	Frame-Relay ATM	Mostly ATM
Transport Network Characteristics	Service Dependent Disconnected LAN's Slow Speed Interconnection	Initial Service-Independent Initial LAN Connectivity through Metropolitan Area Networks (MAN)	Partial Service-Independent Partial MAN's	Widespread Service Integrated Broadband Network—B-ISDN Most Service Independent
Intelligent Network Characteristics	Partial Wireline Support: • Number Translation	Most Wireline Support Partial Wireless Support • Mobility Services (Personal, Terminal)	Full Wireline Support Most Wireless Support	Fully Integrated Wireline/Wireless Support • Seamless Operation • Multi-Mode Terminal • Profile Portability • Dynamic Resource Allocation • Information Format Adaptation

2.6 Standards Requirements

Appropriate standards are fundamental to the establishment of an open, ITS architecture. Standards will enable deployment of consistent, non-interfering, reliable systems on local, regional and national levels. Open standards will further benefit the consumer by enhancing competition for the range of products necessary to implement the ITS user services. Producers benefit from standards because they assure a wide market over which the product can be sold. As deployment occurs, diverse systems will be developed to address the special needs of urban, suburban and rural environments. Standards must ensure interoperability across these implementations without impeding innovation as technology advances and new approaches evolve.

A complete discussion of the standards requirements associated with the ITS Architecture is presented in the companion Standards Development Plan and Standards Requirements Document deliverables. This section provides an overview of this material as it applies to the implementation strategy developed in this deliverable.

2.6.1 Identifying Standards Requirements

The architecture is a framework that is intended to guide the establishment of standards which will enable nationwide ITS interoperability and compatibility. Table 2.6-1 provides interoperability assignments for each of the major system interfaces defined by the architecture. The first column in the table identifies each of the subsystems, and the second column identifies the associated interfaces (either to other subsystems or other interfaced systems as defined by the architecture). As presented in the table, several levels of interoperability ranging from no interoperability to national interoperability are suggested for each of the interfaces. In some cases, only a portion of the interface may need to be standardized, including only the particular set of messages or core data that is required to guarantee the successful delivery of an ITS service. To encourage early deployment and maximum utilization of existing infrastructure, standards requirements for the many internal interfaces within each subsystem (e.g., within a Traffic Management Subsystem) are not addressed by the Architecture.

Table 2.6-1: Major Subsystem Interface Interoperability Assignments

Subsystem	Interfacing Subsystem/System	Interoperability
Commercial Vehicle Administration	Commercial Vehicle Check	regional
Commercial Vehicle Administration	CVO Information Requestor	national
Commercial Vehicle Administration	DMV	national
Commercial Vehicle Administration	Enforcement Agency	regional
Commercial Vehicle Administration	Financial Institution	national
Commercial Vehicle Administration	Fleet and Freight Management	national
Commercial Vehicle Administration	Other CVAS	national
Commercial Vehicle Administration	Planning Subsystem	regional
Commercial Vehicle Check	Commercial Vehicle Administration	regional
Commercial Vehicle Check	Commercial Vehicle Subsystem	national
Commercial Vehicle Subsystem	Commercial Vehicle Check	national
Commercial Vehicle Subsystem	Fleet and Freight Management	none
Emergency Management	E911 or ETS	regional
Emergency Management	Emergency Vehicle Subsystem	regional
Emergency Management	Fleet and Freight Management	national
Emergency Management	Information Service Provider	regional
Emergency Management	Map Update Provider	national
Emergency Management	Other EM	regional
Emergency Management	Personal Information Access	national
Emergency Management	Planning Subsystem	regional
Emergency Management	Remote Traveler Support	national
Emergency Management	Traffic Management	regional
Emergency Management	Transit Management	regional
Emergency Management	Vehicle	national
Emergency Vehicle Subsystem	Emergency Management	regional
Emergency Vehicle Subsystem	Roadway Subsystem	regional
Emissions Management	Map Update Provider	national
Emissions Management	Planning Subsystem	regional
Emissions Management	Roadway Subsystem	product
Emissions Management	Traffic Management	product
Fleet and Freight Management	Commercial Vehicle Administration	national
Fleet and Freight Management	Commercial Vehicle Subsystem	none
Fleet and Freight Management	Emergency Management	national
Fleet and Freight Management	Information Service Provider	none
Fleet and Freight Management	Intermodal Freight Depot	national
Fleet and Freight Management	Intermodal Freight Shipper	regional
Information Service Provider	Emergency Management	regional
Information Service Provider	Financial Institution	national
Information Service Provider	Fleet and Freight Management	none
Information Service Provider	Intermodal Transportation Service Provider	regional
Information Service Provider	Map Update Provider	national
Information Service Provider	Media	product
Information Service Provider	Other ISP	national
Information Service Provider	Parking Management	regional
Information Service Provider	Personal Information Access	national
Information Service Provider	Planning Subsystem	regional
Information Service Provider	Remote Traveler Support	product
Information Service Provider	Toll Administration	regional
Information Service Provider	Traffic Management	regional
Information Service Provider	Transit Management	regional
Information Service Provider	Vehicle	national
Information Service Provider	Weather Service	regional
Parking Management	DMV	national
Parking Management	Enforcement Agency	regional
Parking Management	Financial Institution	national
Parking Management	Information Service Provider	regional
Parking Management	Parking Service Provider	product

Table 2.6-1: Major Subsystem Interface Interoperability Assignments

Subsystem	**Interfacing Subsystem/System**	**Interoperability**
Parking Management	Planning Subsystem	regional
Parking Management	Traffic Management	regional
Parking Management	Transit Management	regional
Parking Management	Vehicle	national
Personal Information Access	Emergency Management	national
Personal Information Access	Information Service Provider	national
Personal Information Access	Map Update Provider	national
Personal Information Access	Transit Management	national
Planning Subsystem	Map Update Provider	national
Planning Subsystem	Traffic Management	regional
Remote Traveler Support	Emergency Management	national
Remote Traveler Support	Information Service Provider	product
Remote Traveler Support	Map Update Provider	national
Remote Traveler Support	Transit Management	product
Roadway Subsystem	Emissions Management	product
Roadway Subsystem	Multimodal Crossings	national
Roadway Subsystem	Traffic Management	product
Roadway Subsystem	Wayside Interface Equipment	product
Roadway Subsystem	Vehicle	national
Toll Administration	DMV	national
Toll Administration	Enforcement Agency	regional
Toll Administration	Financial Institution	national
Toll Administration	Information Service Provider	regional
Toll Administration	Planning Subsystem	regional
Toll Administration	Toll Collection	regional
Toll Administration	Traffic Management	regional
Toll Collection	Toll Administration	regional
Toll Collection	Vehicle	national
Traffic Management	DMV	national
Traffic Management	Emergency Management	regional
Traffic Management	Emissions Management	product
Traffic Management	Enforcement Agency	regional
Traffic Management	Information Service Provider	regional
Traffic Management	Map Update Provider	national
Traffic Management	Other TM	regional
Traffic Management	Parking Management	regional
Traffic Management	Planning Subsystem	regional
Traffic Management	Rail Operations	national
Traffic Management	Roadway Subsystem	product
Traffic Management	Toll Administration	regional
Traffic Management	Transit Management	regional
Traffic Management	Weather Service	regional
Transit Management	Emergency Management	regional
Transit Management	Enforcement Agency	regional
Transit Management	Financial Institution	national
Transit Management	Information Service Provider	regional
Transit Management	Intermodal Transportation Service Provider	regional
Transit Management	Map Update Provider	national
Transit Management	Other TRM	regional
Transit Management	Parking Management	regional
Transit Management	Personal Information Access	national
Transit Management	Planning Subsystem	regional
Transit Management	Remote Traveler Support	product
Transit Management	Traffic Management	regional
Transit Management	Transit Vehicle Subsystem	product
Transit Vehicle Subsystem	Roadway Subsystem	regional
Transit Vehicle Subsystem	Transit Management	product
Transit Vehicle Subsystem	Transit Vehicle	product
Vehicle	Emergency Management	national

Table 2.6-1: Major Subsystem Interface Interoperability Assignments

Subsystem	**Interfacing Subsystem/System**	**Interoperability**
Vehicle	Information Service Provider	national
Vehicle	Map Update Provider	national
Vehicle	Other Vehicle	national
Vehicle	Parking Management	national
Vehicle	Roadway Subsystem	national
Vehicle	Toll Collection	national

In general, the minimal level of standardization necessary to achieve the interoperability goals of the national architecture is suggested by the table. The following rules were used in making the standards assignments:

1. Interfaces between subsystems that are operated and maintained by a single stakeholder do not require standardization to achieve national interoperability. The data formats and communications mechanisms that are used for these interfaces are transparent to the remainder of the architecture. In some cases, national standards are still attainable and beneficial since they may consolidate a market to achieve economy of scale efficiencies (e.g. Traffic Management Subsystem to Roadway Subsystem). For these interfaces, “Product” interoperability is specified in the figure. Such standards also support an optional level of interoperability by enabling various cooperative control options to be implemented based on regional preference. In other cases, the sheer range of application-specific interfaces precludes efficient national standardization and no standard is specified.

   Examples: Traffic Management Subsystem to Roadway Subsystem, Freight and Fleet Management Subsystem to Commercial Vehicle Subsystem.

2. Interfaces connecting subsystems that may be operated by different agencies (interfaces that can span jurisdictional and/or regional boundaries) should be standardized to facilitate the sharing of information between agencies. National standards mitigate issues that may arise as boundaries change and new requirements for information sharing develop over time. In the diagram, “Regional” interoperability is specified where the underlying coordination issues are regional, rather than national, in scope. For instance, there is no real requirement for a Traffic Management Subsystem in California to be able to communicate and coordinate with a Traffic Management Subsystem in New York. Two different regional dialects for Traffic Management Subsystem communications could evolve in the two geographically isolated subsystems without significant impact to national interoperability goals.

   Example: Traffic Management Subsystem to Transit Management Subsystem, Traffic Management Subsystem to Information Service Provider, Traffic Management Subsystem to Traffic Management Subsystem.

3. Interfaces to the mobile subsystems (Vehicle Subsystems, Personal Information Access Subsystems) are a major focus in the national architecture since the same mobile subsystem

should be able to roam the nation and use the local infrastructure to support ITS services. “National” interoperability is specified for all interfaces to mobile subsystems except where both the mobile subsystem and interfacing infrastructure are owned and operated by the same user.

Examples: Information Service Provider to Personal Information Access Subsystem, Toll Collection Subsystem to Personal Vehicle Subsystem, Commercial Vehicle Subsystem to Commercial Vehicle Check Subsystem.

4. As a minimum, the key application data that is communicated across each of the identified interfaces will be specified. This degree of specification preserves the choice of communications media/frequency and protocols for the implementing agencies. National standard interfaces to mobile subsystems must be more fully specified to ensure the mobile subsystem can communicate with the local ITS infrastructure or other mobile subsystems regardless of where in the nation it is.

Identification of standards requirements for each subsystem interface may lead to some redundancy; for example, general purpose message elements such as location reference and time measures should be defined once and be applicable across multiple interfaces. There are numerous groups that are already examining this type of issue. The Standards Development Organizations (SDOs) will seek coordination and commonality as a natural part of their process in developing the ITS-related standards. Also, some of the market packages have optional features that may be implemented as part of future upgrades to an initial basic implementation. Thus, the constraints levied by standards on initial market package deployments may be less than Table 2.6-1 suggests.

2.6.2 Addressing the Standards Requirements

The standards requirements associated with ITS may be addressed in three general ways: (1) application of existing standards to ITS, (2) enhancing existing standards to more specifically accommodate ITS functions, and (3) development of new standards for emerging technologies and applications. It is anticipated that it will be possible to produce valid ITS implementations that almost exclusively utilize existing or emerging commercial communications technology and standards. Based on this expectation, emphasis will be placed on standardizing the data to be communicated and not on the communications media or protocols.

Based on the interoperability assignments highlighted in the previous section, the standardization needs associated with each of the market packages can be determined. This essentially aligns the standards with the deployments they are intended to support. This relationship between market packages and standards can then be used to prioritize standards relative to their importance to near-term deployment. Note that standards priorities will be somewhat independent from the “National”, “Regional”, “Product”, and “None” assignments developed in this section. Both priority and non-priority “National” interfaces may be identified, for example. The distinction is that while both interfaces require standards, the priority interfaces are viewed as critical to the early rollout of ITS services. Non-priority standards may not be as urgent, may have dependencies on the definition of priority interface standards, or may be based on as yet undefined or immature technology. Similarly, a high priority standard may be identified for an interface requiring only “product” interoperability. This may occur where there is early and significant deployment activity for the related services and there is significant economic benefit forecast for early standardization. In all cases, it will be desirable to specify a phased set of compatible standards that can be implemented over time for each interface.

Standards dependencies are "soft" since the absence of published standards may be a deterrent to, but will not prevent, a product developer from pursuing new markets. Historically, standards have followed commercial markets rather than led; it is assumed that this general principle will be repeated for ITS deployments. Where there is clear benefit (e.g., existing market opportunity) to early deployment, it is understood that many market package deployments will occur before the related standards are available. Such early deployments will ultimately be at risk since any pre-existing equipment is likely to conflict with the standard which is finally adopted. The alternative, to somehow regulate entry to the market until the standards are complete is neither viable nor attractive. Early deployments are necessary to provide the SDOs an understanding of all the issues at hand; they provide valuable input to ensure the standards which are finally adopted are viable.

A complete treatment of the planned development of ITS standards and their relationship to the National Architecture effort is included in the Standards Development Plan deliverable. Additional recommendations on standards adoption, supporting legacy systems, and other issues which are related to standards development are identified in section 5.1 of this document.

2.7 Identifying Early Market Packages

The market packages presented in section 2.2 are inter-related and are also dependent on external factors such as technology advancement, policy change, and development of common interface standards as detailed in sections 2 and 3 of this document. Moreover, each market package provides different benefits, lends itself to different cost recovery mechanisms, and is subject to different levels of market influence. It is through the interplay of these influences that ITS deployments will occur over time.

Figure 2.7-1 is a generalized view of the factors which influence deployment of each market package. Each of these factors is discussed in the Implementation Strategy in the indicated section. An efficient deployment strategy can reduce the need for the motivators presented on the left hand side of the figure (e.g., Strategic Investment) by recognizing the time-dependent nature of the impediments on the right hand side of the figure (e.g., Technology Constraints) in the deployment strategy.

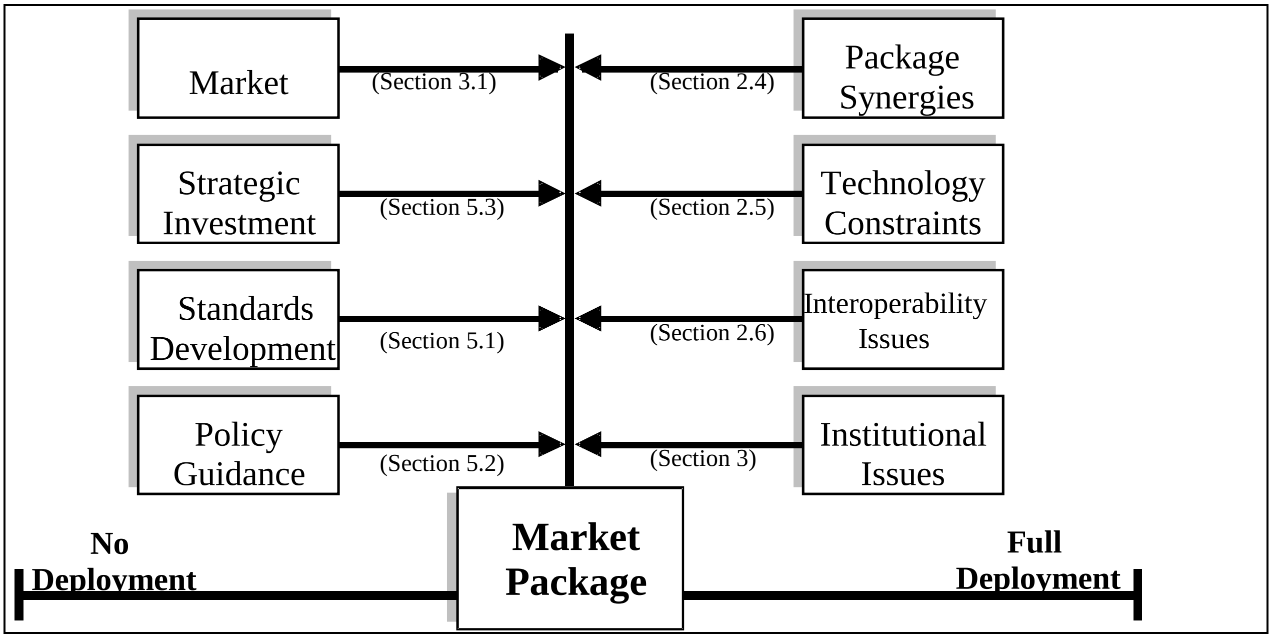


Figure 2.7-1: Factors Affecting Market Package Deployment

The deployment impediments identified in figure 2.7-1 are generally reduced over time. As ITS deployment is initiated and basic market packages are deployed, the deployment of more advanced market packages which build on the existing capabilities will be enabled. As technology advances, technical constraints for a market package should be reduced. As the required standards are developed and approved, interoperability issues are resolved. Thus, as a natural progression, market demand may overcome the challenges associated with an increasing number of market packages over time as the impediments are reduced. The implementation strategy then requires a forecast of this market driven deployment coupled with a plan for judicious application of additional motivators where this forecast natural progression is unsatisfactory.

By considering each of these factors, a subset of the market packages have been highlighted as important early deployments. Such market packages are identified as *Early Market Packages* in this section. The evaluation leading to this market package prioritization is based on the supporting analysis in sections 2, 3 and 5 in this document as highlighted in figure 2.7-1. The Early Market Packages are those packages that meet, or nearly meet, three general criteria:

- *Enabling function.* An Early Market Package satisfies fundamental requirements that enable implementation of a range of more advanced packages that can be selectively implemented over time to meet local needs.
- *Feasible.* An Early Market Package can be implemented with existing technologies, is not dependent on forthcoming national standards for basic implementations, and is also subject to

limited non-technical risk since existing institutions and policy are also adequate to support basic implementations.

- *Established Benefit.* An Early Market Package has already been implemented in several locations around the nation which is an indicator of potential demand for the package. Moreover, these preliminary deployments have demonstrated tangible benefits in an operational setting. As such, a Early Market Package is shrouded by fewer unknowns and is likely to subject the local implementor to limited risk. These criteria indicate that market influence is likely to be a significant near-term force in enabling early deployment for the identified packages.

In short, the Early Market Packages appear to be early winners due to a promising combination of low risk implementation characteristics, developing public or private markets for the packages, and tangible system or user benefits.

Table 2.7-1 evaluates the market packages against these attributes and identifies the Early Market Packages. A summary of the source and approach for developing each dimension of the evaluation summarized in the table is described.

Enabling Function: Market packages that are checked (✓) are highlighted in the market package synergy analysis in section 2.4 of this Implementation Strategy as providing critical early capabilities that will enable future deployments of more advanced services.

Technology Supports: The majority of the market packages require only relatively mature, commercially available technologies for implementation. Market packages that are checked (✓) are identified in section 2.5 of this Implementation Strategy as not reliant on an identified critical technology area. In interpreting the analysis from section 2.5, basic implementations were also considered. For instance, the HOV and Reversible Lane Management market package is identified in section 2.5 as reliant on a critical vehicle passenger occupancy verification technology. Since useful implementations of this market package can be achieved, even without this technology, this market package is still identified as technically feasible in table 2.7-1.

Standards Not Required: Market packages that are checked (✓) are not dependent on forthcoming national standards for basic implementations as analyzed in section 2.6. In reviewing the standard interface requirements associated with each of the market packages, interfaces that are fundamental to provision of a service were distinguished from optional interfaces. Also, it was recognized that even fundamental “national interoperability” requirements will often be met through multiple, competing product-specific “standards”. For instance, the Autonomous Route Guidance market package is identified as requiring a national interoperability interface to a Map Update Provider. Viable implementations can occur in the absence of a nationally prescribed standard using proprietary map databases that provide the required coverage. Emerging standards efforts such as the Spatial Data Transfer Standard and Open GIS may ultimately enable plug and play interoperability between different map databases. In the mean time, viable products can and will be developed based on the existing proprietary standards. These assumptions to some degree accurately reflect the interplay of market forces and standards and the evolution through proprietary interfaces to open standards as the products and market matures. All market packages for which standardization is not a major roadblock to implementation are identified in the column.

Few Institutional Issues: Market packages that are subject to limited non-technical risk per the analysis included in section 3 of this Implementation Strategy are checked (✓). Market packages that were identified as having associated interjurisdictional issues, liability implications, antitrust issues, privacy issues, or regulatory constraints in section 3 are not checked in the column.

Established Benefit: Results from the separate “Performance and Benefits Study” deliverable were used as a basis for this column. Only market packages that were highlighted in the Performance and Benefits study deliverable as particularly beneficial are checked in this column. To further reduce the set of candidate market packages, only those market packages which have existing or currently emerging implementations were considered since the benefits associated with these market packages can be more reliably estimated.

The Early Market Packages are those that best satisfy the combination of these criteria as identified in the last column of table 2.7-1. In some cases, a compelling benefit, significant market activity, or evident public sector interest (for instance, through inclusion in the Intelligent Transportation Infrastructure initiative) caused a market package to be identified as early even though there may be remaining standards or institutional issues associated with that package. The shaded boxes in the table identify where a market package designated as early is dependent on development of a standard or resolution of institutional issues; such activities are crucial near-term activities to support successful deployment of ITS.

Table 2.7-1: Identifying Early Market Packages

Market Package	Enabling Function	Technology Available	Standards not Reqd	Few Institutional Issues	Established Benefit	Early Package
Traffic Management						
Network Surveillance	✓	✓	✓	✓	✓	✓
Probe Surveillance	✓	✓	▨	▨	✓	✓
Surface Street Control	✓	✓	✓	✓	✓	✓
Freeway Control	✓	✓	✓	✓	✓	✓
HOV and Reversible Lane Mgmt		✓	✓		✓	✓
Traffic Information Dissemination		✓	✓	✓	✓	✓
Regional Traffic Control	✓	✓	▨	▨	✓	✓
Incident Management System		✓	✓	▨	✓	✓
Traffic Network Performance Eval		✓	✓			
Dynamic Toll/Parking Fee Mgmt	✓	✓	▨	▨	✓	✓
Emissions and Environmental Hazards Sensing		✓				
Virtual TMC and Smart Probe Data		✓				
Standard Railroad Grade Crossing		✓	✓	✓	✓	✓
Advanced Railroad Grade Crossing			✓			
Railroad Operations Coordination		✓	✓	✓		✓
Transit Management						
Transit Vehicle Tracking	✓	✓	✓	✓	✓	✓
Transit Fixed-Route Operations	✓	✓	✓	✓	✓	✓
Demand Response Transit Operations	✓	✓	✓	✓	✓	✓
Transit Passenger and Fare Mgmt	✓	✓	▨	✓	✓	✓
Transit Security		✓	▨	▨		✓
Transit Maintenance		✓	✓	✓		✓
Multi-modal Coordination		✓	▨	▨		✓
Traveler Information						
Broadcast Traveler Information	✓	✓	▨	✓	✓	✓
Interactive Traveler Information	✓	✓	✓	✓	✓	✓
Autonomous Route Guidance	✓	✓	✓	✓	✓	✓
Dynamic Route Guidance		✓		✓		
ISP Based Route Guidance		✓				
Integrated Transportation Mgmt/ Route Guidance						
Yellow Pages and Reservation		✓		✓		
Dynamic Ridesharing		✓				
In Vehicle Signing		✓				
Advanced Vehicle Systems						
Vehicle Safety Monitoring	✓	✓	✓	✓	✓	✓
Driver Safety Monitoring			✓			
Longitudinal Safety Warning			✓	✓		
Lateral Safety Warning			✓	✓		
Intersection Safety Warning						
Pre-Crash Restraint Deployment			✓	✓		
Driver Visibility Improvement			✓			
Advanced Vehicle Longitudinal Control			✓			

Market Package	Enabling Function	Technology Available	Standards not Reqd	Few Institutional Issues	Established Benefit	Early Package
Advanced Vehicle Lateral Control			✓			
Intersection Collision Avoidance						
Automated Highway System						
Commercial Vehicle Operations						
Fleet Administration	✓	✓	✓	✓	✓	✓
Freight Administration		✓	✓	✓	✓	
Electronic Clearance	✓	✓	▨	✓	✓	✓
CV Administrative Processes	✓	✓	▨	✓	✓	✓
International Border Electronic Clearance		✓			✓	
Weigh-In-Motion		✓	✓	✓	✓	
Roadside CVO Safety	✓	✓	▨	✓	✓	✓
On-board CVO Safety						
CVO Fleet Maintenance		✓	✓	✓		
HAZMAT Management		✓	▨	▨	✓	✓
Emergency Management						
Emergency Response	✓	✓	▨	▨	✓	✓
Emergency Routing		✓	✓	✓	✓	✓
Mayday Support	✓	✓	▨	▨	✓	✓
ITS Planning	✓	✓	▨	▨	✓	✓

Notes: Check marks (✓) indicate the market package meets the criteria identified in the column heading.
Shaded cells indicate areas requiring resolution to support identified Early Market Packages.
See supporting text for additional information.

Further rationale is provided for each of the Early Market Packages in the following:

Traffic Management:

Network Surveillance. This market package provides the basic sensing elements for traffic management. It is the foundation upon which control and management systems can be implemented. It is also a vital source of information supporting real-time traveler information systems which makes it among the most crucial of the identified "core functions".

Probe Surveillance. This market package is a potentially cost-effective alternative to infrastructure surveillance. The traffic information that is made available through this package is a key enabler for other traffic management and traveler information services.

Surface Street Control. Benefits are well established for this market package and existing technologies and institutional arrangements support its deployment. Interjurisdictional issues which may be associated with broader implementations are also resolvable based on the success of existing wide area implementations. The imminent arrival of the NTCIP standard further facilitates advanced implementations.

Freeway Control. See surface street control.

Traffic Information Dissemination. The equitable distribution of basic traffic information through Variable Message Signs and Highway Advisory Radio implemented through this market package provides immediate benefit to the traveling public using established technologies and without the need for new standards or investment in new in-vehicle equipment. The implementations represented by this market package have been, and will continue to be, judiciously deployed as the technical and non-technical challenges of more advanced en-route driver information systems are addressed.

Regional Traffic Control. Traffic control strategies are increasingly regional in scope with emphasis on improving flow along major travel corridors. The potential benefits of integrated regional strategies have been clearly established through many trial implementations. Such implementations are also one of the focus areas within the Intelligent Transportation Infrastructure Initiative (see section 2.8). The peer-to-peer interjurisdictional arrangements and regional communications internetworking that enable regional control strategies facilitate implementation of many of the other traffic control and traveler information market packages.

Incident Management. Since incidents account for a significant percentage of congestion, this market package is a key early deployment which is actively being deployed in larger metropolitan areas. Preliminary implementations that achieve significant benefit are possible without new standards activity. Interjurisdictional issue resolution which is inherent in this market package has already successfully occurred in many areas.

Dynamic Toll/Parking Fee Management. This market package provides tangible benefits to users when compared to manual systems and is generally well accepted and widely deployed. This market package is also naturally self sustaining through user fees. The market package provides core dedicated short range communications, basic driver interface, and AVI functions that can enable several other market packages.

Standard Railroad Grade Crossing. Passive warning systems and active warning devices may be augmented with standard traffic control devices and interconnected with adjacent intersections to provide safer and more efficient management of highway traffic at highway-rail intersections. Each of these capabilities can be implemented with today’s technology and without need for major new standardization efforts or institutional change.

Railroad Operations Coordination. Many rail operations today have detailed and up-to-date information available on the location and planned itinerary for each train in the system. This information may be made available to highway traffic managers with existing technology and relatively modest institutional and standardization impediments. This rail schedule information may be applied to anticipate highway-rail intersection closures, a significant source of delay in many areas. Adaptive regional traffic control strategies may take this advanced information into account to minimize the impact of rail operations.

Transit Management:
Transit Vehicle Tracking. This market package provides the communications between vehicles and transit centers and current vehicle location information that is required by other packages.

The technology of Automatic Vehicle Location is proven and in use by many transit agencies. While insufficient data exists at this time to validate transit benefits, its usage in commercial transportation such as the trucking industry has shown it to be beneficial.

Transit Fixed Route Operations. This market package provides many of the operations and planning functions required in an automated transit management system. It is in place in many parts of the United States with many vendors providing automated transit management system software products.

Transit Demand Response Operations. As with the fixed route operations package, this market package provides many of the core operations and planning functions that would be required by the larger demand responsive fleet.

Transit Passenger and Fare Management. This market package provides immediate and tangible benefit to transit users who enjoy the convenience of an electronic fare medium. The benefits of more efficient, cashless operations also accrue to the implementing transit agencies. These deployments are possible in the interim while industry standards move towards the ultimate goal of a common fare medium that transcends transportation modes and regions and may be applied in other consumer transactions.

Transit Security. ITS applications which improve the security of transit users are one of the tools available to transit agencies. Current US DOT support for these systems is demonstrated by their inclusion within the Intelligent Transportation Infrastructure initiative. Potential privacy issues associated with this market package must be considered and implementations selected which strike an appropriate balance between individual privacy and personal safety.

Transit Maintenance. Advanced applications which enhance maintenance monitoring and support for transit vehicles can improve overall transit system performance and make operations more efficient.

Multi-modal Coordination. This market package provides real-time coordination between traffic and transit management that can reduce and improve the consistency of transit travel times. Potential inter-jurisdictional issues must be resolved to support local implementation. Careful application is necessary to avoid adverse impacts to the overall efficiency of the network. Current US DOT support for these systems is demonstrated by their inclusion within the Intelligent Transportation Infrastructure initiative.

Traveler Information:

Broadcast Traveler Information. It satisfies the core criteria in that most of the collection and processing capabilities of this package can be used for other ATIS packages. This package provides many of the traveler information functions in basic forms. It is currently in use today through mediums such as FM subcarrier in Europe. This market package does require the establishment of national standards for basic viable implementations.

Interactive Traveler Information. This package is a foundation for interactive ATIS and provides the interconnects for the two-way interchange. Examples of current usage are kiosks, telephone, and as an emerging information provider for on-line services and the Internet. Stated-preference surveys indicate that pre-trip access to information through these existing access mechanisms will be well received. More advanced implementations which seamlessly cater to the mobile traveler with en-route information require additional standards work.

Autonomous Route Guidance. Basic autonomous implementations are enjoying preliminary market success, at least in niche markets such as rental fleets. These deployments are not predicated on further technology, institutional policy, or standards development. The in-vehicle equipment provides core position location and routing functions that may be applied to a host of more advanced packages.

Advanced Vehicle Systems

Vehicle Safety Monitoring. This market package provides the processing and display basis for most of the AVSS market packages. In various simplified forms, this package already exists in vehicles, e.g., brake light outage indicators, electrical system malfunctions indicators, etc. The benefits of these systems are validated by their growing usage by automobile manufacturers. Whether the existing electrical systems will accommodate requirements from this package is a current issue, especially in light of developments of data bus architectures such as J1850

Commercial Vehicle Operations:

Fleet Administration. This market package provide the capabilities of Automatic Vehicle Location and Fleet Management. These capabilities are in place and have proven benefit to the trucking industry.

Electronic Clearance. This market package established the dedicated short range communications between the vehicle and roadside that supports electronic clearance as well as many of the other market packages that are extended applications dependent on the short range communications link. Time savings for participating carriers have been measured and reported in several operational tests.

CV Administrative Processes. This market package establishes electronic communications between the commercial vehicle administration and fleet management subsystems. This connectivity enables carrier enrollment that provides a basis for paperless trucking and also supports many of the more advanced commercial vehicle services. An area of active interest which forms a foundation for programs like IRP and IFTA.

Roadside CVO Safety. The promise of improved safety is a principal motivator for application of ITS to commercial vehicle operations. The more effective and focused roadside safety inspections offered by this market package most directly address this objective. This market package also develops the roadside equipment and interfaces that will ultimately leverage the separate On-board CVO Safety market package.

HAZMAT Management. Hazardous material management addresses one of the more serious safety issues associated with commercial vehicle operations. The potential for this market package to address key public safety risks justifies designation as an early market package in spite of several existing roadblocks to its implementation. Including this market package in the set of Early Market Packages is in effect a recommendation for prioritization of the standards development efforts and resolution of the non-technical issues associated with this market package.

Emergency Management:

Emergency Response. This market package is central to developing coordinated emergency management including emergency management, traffic, and transit stakeholders. This market package is a key component to enhancing safety in conjunction with the Incident Management and Mayday Support market packages.

Emergency Routing. An area of active private sector interest and public sector procurement, this market package leverages the same vehicle location, wide area digital communications, dispatch support, and in-vehicle interactive interface technologies that are instrumental to the related commercial and transit fleet support market packages. New standards are not required to support basic implementations. Progressive implementations which address more extensive inter-agency coordination in routing may be added as new standards become available and are adopted for the implementing region.

Mayday Support. Active private sector deployment of Mayday systems as value-added options on new automobiles highlights the potential for this package as an early deployment. Based on outreach performed through the architecture program and other industry activity, this appears to be an area of near-term and active development. Early deployments establish interactive, digital communications capabilities in the vehicle which can be leveraged by other market packages. National standards may enhance the performance and reliability of the service provided.

ITS Planning. This market package is key to better utilizing the transportation information collecting during operation of ITS systems to facilitate and enhance the quantitative support for transportation planning. Early implementations may consider the existing planning tools that are used in the region and align the historical data collected during transportation system operation to support these interfaces. Resolution of inter-jurisdictional and standardization issues will enable tighter integration and solutions which are transferable between systems and regions.

2.8 Intelligent Transportation Infrastructure

On January 10, 1996, Secretary of Transportation Federico Pena set a national goal: To build an Intelligent Transportation Infrastructure across the United States. As part of this goal, a very tangible target was set for implementing this Intelligent Transportation Infrastructure (ITI) in the 75 largest metropolitan areas within 10 years. The concept of an ITI is compelling since it focuses attention on what can be implemented today in metropolitan areas where transportation problems are most pronounced.

This section takes a closer look at the Intelligent Transportation Infrastructure and connects its nine elements with the National Architecture definition and market packages which were defined earlier in section 2. Through this mapping, the subset of the national architecture is identified as a national interoperability framework within which an Intelligent Transportation Infrastructure may be deployed. The remainder of this Implementation Strategy then emphasizes the ITI elements that are the best candidates for near term implementation.

2.8.1 Intelligent Transportation Infrastructure Overview

The U.S. DOT has defined nine components within the ITI:

1. *Regional Multimodal Traveler Information System.* This system is a repository for current, comprehensive and accurate roadway and transit performance data. It directly receives this data from a variety of public and private sector sources, combines and packages this data, and provides the resulting information to travelers and other customers via a variety of distribution channels. The system may be a single physical facility or an inter-connected set of facilities.
2. *Traffic Signal Control System.* This system provides coordinated traffic signal control across the metropolitan area. Traffic information is shared between jurisdictional systems as necessary to support the extended coordination area. Variations in control sophistication range up to automated generation of timing plans and adaptive traffic signal control.
3. *Freeway Management System.* This system monitors traffic conditions on the freeway system, identifies recurring and non-recurring flow impediments, implements appropriate control and management strategies (such as ramp metering or lane control), and provides critical information to travelers using dissemination methods such as variable message signs and highway advisory radio.
4. *Transit Management System.* This system provides reliable and timely bus position information to the dispatcher. The dispatcher or a central computer compares the actual location with the scheduled location, enabling positive action to improve schedule adherence and expanded information to the Traveler Information System component. In addition, on-board sensors automatically monitor data such as vehicle passenger loading, fare collection, drive line operating conditions, etc., providing for real-time management response. In the event of an on-board emergency, the dispatcher can inform the police and direct them to the vehicle’s exact location.
5. *Incident Management Programs.* An organized system for quickly identifying and responding to incidents that occur on area freeways and major arterials. The objectives are to rapidly respond to incidents with the proper personnel and equipment, to aid accident victims, and to facilitate the rapid clearance of the accident from the roadway. Timely

execution of these activities will save lives and minimize the delay and frustration of the traveling public. To accomplish this, real-time input from the freeway and arterial surveillance systems and the agencies responsible for managing them is critical.

6. *Electronic Fare Payment System*. The system(s) include hardware and software for roadside, in-vehicle, and in-station electronic payment of transit fares, parking fees, etc. Both debit and credit systems would possibly be included. The system eliminates the need for travelers to carry exact fare amounts and facilitates the subsequent implementation of a single fare payment medium.
7. *Electronic Toll Collection System.* The system(s) include hardware and software for roadside and in-vehicle use which will allow drivers to pay tolls without stopping. It includes driver payment cards or tags, financial and card accounting system(s), roadside systems at mainline plazas or toll road entry and exit points, and a communications system between vehicles and the roadside. The system performs automated vehicle identification, automatic determination of tolls for differing classes of vehicles, automated enforcement of violations, and flexibility in financial arrangement.
8. *Railroad Grade Crossing.* This system supplies real-time information on train position and estimated time of arrival at Highway-Rail Intersections and interactive coordination between highway TMCs and rail operations centers. This ITI element will interface with Advanced Train Control Systems at central dispatch stations and on-board the locomotive, Vehicle Proximity Alerting Systems on board special classes of vehicles (e.g., school buses, hazardous materials haulers, and emergency vehicles), and Remote Monitoring Systems at Highway Rail Intersections.
9. *Emergency Management Services:* This system supports coordination of emergency services across jurisdictional boundaries, makes emergency fleet management more efficient through application of AVL and dispatch-support systems, provides coordination with traffic management systems to further reduce emergency response times, and improves HAZMAT material tracking and HAZMAT incident response through provision of timely and accurate information to emergency personnel

2.8.2 Relating Intelligent Transportation Infrastructure to National Architecture

This section provides a direct technical mapping between the elements defined by ITI and the equivalent elements defined by the National Architecture.

As defined in section 2.1, the National Architecture consists of nineteen interconnected subsystems. Each subsystem is, in turn, made up of at least one equipment package. Market Packages provide another perspective that groups equipment packages that must be deployed together to provide a service. To define an “ITI Architecture”, the subset of these National Architecture elements that is necessary to support the Intelligent Transportation Infrastructure must be identified.

The nine Intelligent Transportation Infrastructure elements neatly correspond with a subset of the physical subsystems defined by the National Architecture as presented in table 2.8-1. A more detailed view of the applicable National Architecture requirements is developed by mapping the functional description for each Intelligent Transportation Infrastructure element to the National Architecture Market Packages. To accomplish this, the table lists the major functions identified for each of the Intelligent Transportation Infrastructure elements and selects the Market Packages that provide the same capabilities.

Table 2.8-1: Relating Intelligent Transportation Infrastructure to National Architecture

Intelligent Transportation Infrastructure		National Architecture	
Element	**Identified Functions**	**Subsystem**	**Equivalent Market Packages**
Regional Multimodal Traveler Information	• Real-time Multi-Modal Data Repository • Broadcast Information Distribution • Interactive Information Distribution • Central or Distributed Facilities	**Information Service Provider, Remote Traveler Support, Personal Info Access, Vehicle**	• Broadcast Traveler Information • Broadcast Traveler Information • Interactive Traveler Information • Interactive Traveler Information
Traffic Signal Control System	• Monitors Arterial Network Traffic • Range of Adaptive Control Strategies • Area-wide Signal Coordination • Integration with Freeway Management	**Traffic Management, Roadway**	• Network Surveillance • Surface Street Control • Regional Traffic Control • Regional Traffic Control
Freeway Management System	• Monitors Freeway Conditions • Identifies Flow Impediments • Ramp Metering/Lane Controls • HARs/VMSs	**Traffic Management, Roadway**	• Network Surveillance • Probe Surveillance • Freeway Control • HOV and Reversible Lane Management • Traffic Information Dissemination
Transit Management System	• Monitors Transit Vehicle Position • Disseminates Real-Time Schedules • Computer-Aided Dispatch • Vehicle Passenger Loading • Fare Management • Vehicle Condition Monitoring • On-Board Safety Monitoring • Coordination with Traffic Management	**Transit Management, Transit Vehicle**	• Transit Vehicle Tracking • Transit Vehicle Tracking • Transit Fixed Route Operations • Demand Response Transit Operations • Transit Passenger and Fare Management • Transit Passenger and Fare Management • Transit Maintenance • Transit Security • Multi-modal Coordination
Incident Management Program	• Policy and Operations Agreement • Incident Detection/Verification • Incident Response/Clearance	**Traffic Management**	? Policy separate from architecture • Incident Management System • Incident Management System
Electronic Fare Payment Systems	• Credit or Debit Card Support • Payment at Station/Stop or In-Vehicle	**Transit Management, Transit Vehicle, Remote Traveler Support**	• Transit Passenger and Fare Management • Transit Passenger and Fare Management
Electronic Toll Collection Systems	• Short Range Communications • Automated Vehicle Identification • Vehicle Class Differentiation • Automated Enforcement • Credit/Debit Flexibility	**Toll Admin, Toll Collection, Vehicle**	• Dynamic Toll/Parking Fee Management • Dynamic Toll/Parking Fee Management • Dynamic Toll/Parking Fee Management • Dynamic Toll/Parking Fee Management • Dynamic Toll/Parking Fee Management
Railroad Grade Crossing	• Improve and automate HRI warnings • Provide advanced warning of closures • Coordinate signal control with rail movements	**Traffic Management, Roadway**	• Standard Railroad Grade Crossing • Rail Operations Coordination • Rail Operations Coordination
Emergency Management Services	• Coordinate Regional Response • AVL and Fleet Management Support • Coordination with Traffic Management	**Emergency Management, Emergency Vehicle**	• Emergency Response • Emergency Routing • Emergency Routing

Reviewing the previous table, the following abbreviated list of Market Packages support the Intelligent Transportation Infrastructure:

- Network Surveillance
- Probe Surveillance
- Surface Street Control
- Freeway Control
- Incident Management System
- Regional Traffic Control
- Traffic Information Dissemination
- HOV and Reversible Lane Management
- Dynamic Toll/Parking Fee Management
- Standard Railroad Grade Crossing
- Railroad Operations Coordination
- Broadcast Traveler Information
- Interactive Traveler Information
- Transit Vehicle Tracking
- Transit Fixed Route Operations
- Transit Demand Response Operations
- Transit Passenger and Fare Management
- Transit Maintenance
- Transit Security
- Multi-modal Coordination
- Emergency Response
- Emergency Routing

As the focal point for most of the deployment analysis performed for the National Architecture, the Market Packages provide a direct mapping to the complete set of required subsystems and equipment packages, the associated standard interface requirements, and the strategy for deploying the service.

Note that many of the ITI market packages include a mix of equipment; not all of which would normally be considered as “public infrastructure” and included in ITI under a strict definition. For instance, two traveler information market packages are required to support ITI; however, these market packages include vehicle and personal information access (e.g., personal computer) equipment that would not be classified as infrastructure and would not normally be eligible for public funds. Figure 2.8-1 presents all of the subsystems and interconnections necessary to support the Market Packages associated with Intelligent Transportation Infrastructure. This yields an inclusive view of ITS which includes elements that are not public infrastructure but are required for the ITI to provide a service to end-users.

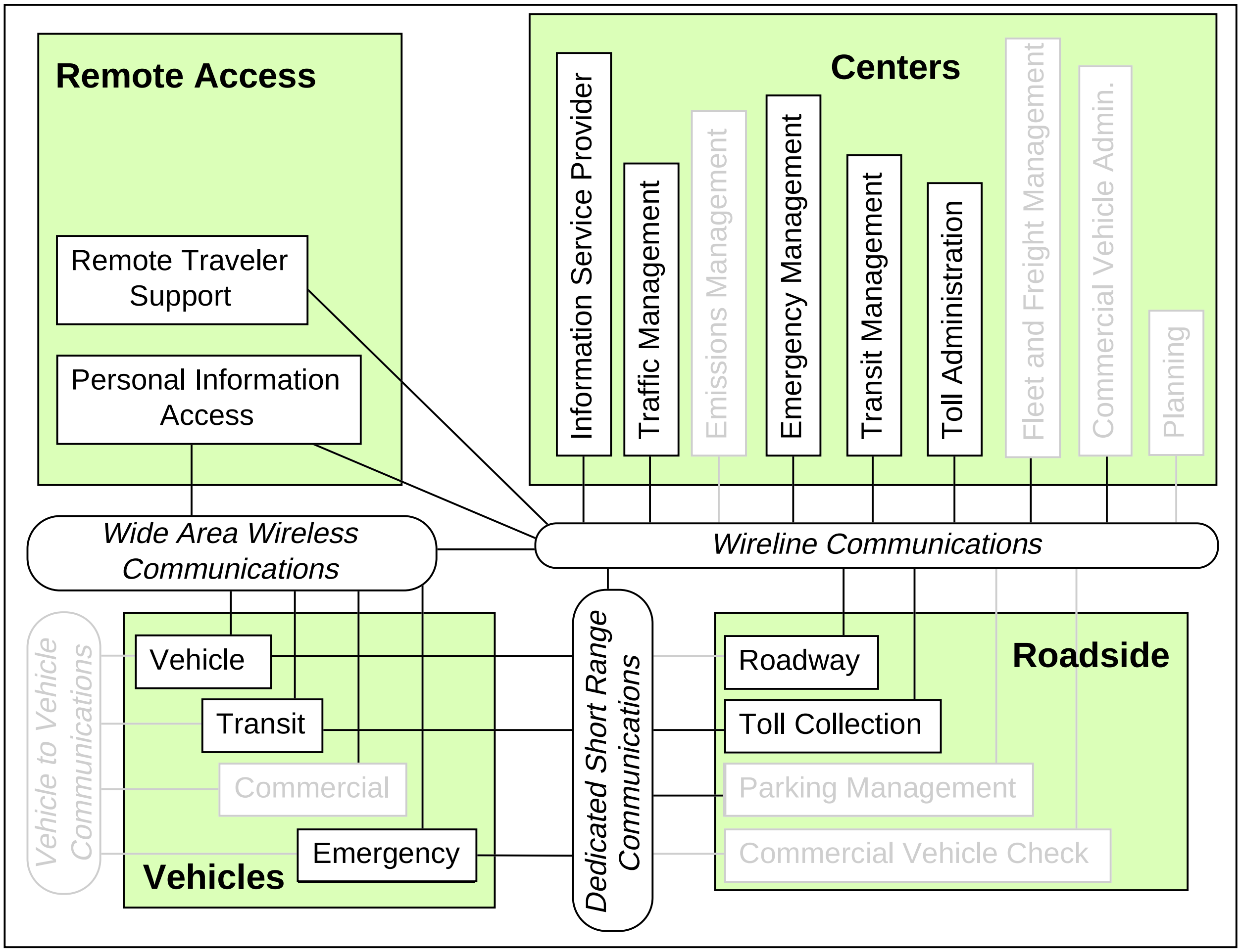


Figure 2.8-1: National Architecture Framework for Intelligent Transportation Infrastructure

2.8.3 Comparing Intelligent Transportation Infrastructure to Early Market Packages

The previous section translated ITI into a subset of the market packages defined by the National Architecture. Section 2.7 provides a similar list of *Early Market Packages* which constitute the key early deployments identified by this architecture implementation strategy. Table 2.8-2 presents the Early Market Packages, and compares this list with the market packages that support ITI. As can be seen, the ITI market packages are a focused subset of the Early Market Packages. This additional focus is a natural by-product of the comparatively focused objectives of ITI The ITI concentrates on metropolitan areas and public infrastructure. This focus provides clarity but also omits several areas that are addressed by the National Architecture due to its more comprehensive scope. For instance, Early Market Packages defined by the Architecture include CVO services. Early Market Packages also include autonomous route guidance systems, mayday services, and other consumer elements that are produced, purchased, owned, and operated within the private sector.

Table 2.8-2: Comparing ITI to Early Market Packages

Market Packages	Early	ITI	Explanation
Traffic Management			
Network Surveillance	✓	✓	
Probe Surveillance	✓	✓	
Surface Street Control	✓	✓	
Freeway Control	✓	✓	
Incident Management System	✓	✓	
Regional Traffic Control	✓	✓	
HOV and Reversible Lane Management	✓	✓	
Traffic Information Dissemination	✓	✓	
Dynamic Toll/Parking Fee Management	✓	✓	
Standard Railroad Grade Crossing	✓	✓	
Rail Operations Coordination	✓	✓	
Transit Management			
Transit Vehicle Tracking	✓	✓	
Transit Fixed Route Operations	✓	✓	
Demand Response Transit Operations	✓	✓	
Transit Passenger and Fare Management	✓	✓	
Transit Maintenance	✓	✓	
Transit Security	✓	✓	
Multi-Modal Coordination	✓	✓	
Traveler Information			
Broadcast Traveler Information	✓	✓	
Interactive Traveler Information	✓	✓	
Autonomous Route Guidance	✓		An area of active private sector interest that provides tangible benefits to the user and yields a potential in-vehicle building block for advanced systems.
Commercial Vehicle Ops			
Fleet Administration	✓		Stakeholder area not included in ITI
Electronic Clearance	✓		Stakeholder area not included in ITI
CV Administrative Processes	✓		Stakeholder area not included in ITI
Roadside CVO Safety	✓		Stakeholder area not included in ITI
HAZMAT Management	✓		Stakeholder area not included in ITI
Emergency Management			
Emergency Response	✓	✓	
Emergency Routing	✓	✓	
Mayday Support	✓		Included to address key rural service need and reflect current private sector activity in this area
ITS Planning			
ITS Planning	✓		Package focuses on the functions and interfaces that support improved access to and application of operational ITS data in the planning process.

3. Implementor Roles And Deployment Implications

An integral component of the National Architecture analysis was to consider the deployment of ITS systems within the context of existing and emerging institutional constraints and arrangements. For this reason, the National Architecture is comprised of two major technical layers, a Transportation Layer and a Communication Layer, which are constrained by and service an Institutional Layer. The Transportation Layer and Communication Layer, defined in section 2, together provide the technical framework within which interoperable systems may be implemented. The Institutional Layer introduces the policies, funding incentives, working arrangements, and jurisdictional structure that support the technical layers of the architecture. This institutional layer provides the basis for understanding who the implementors will be and the roles these implementors could take in implementing architecture-based ITS systems. This chapter provides an overview of the institutional layer, with a special focus on implementor roles and deployment implications.

3.1 The Institutional Layer

As depicted in figure 3.1-1, there are a host of actors that make up the institutional layer. However, within the realm of public sector investment, the relationships have become rather established. This is in large part because ITS deployment decisions can be considered part-and-parcel of the larger transportation investment decision-making process. This process has matured over the last 50 years of major infrastructure development (e.g., the interstate highway system). A cornerstone of this process is the strong legislative underpinning stemming from Title 23 of the United States Code (USC), the most recent reauthorization of which was the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). From the vantage of the private sector, both the automotive and communications industries have been major participants in developing various consumer products and services related to ITS. This section provides an overview of the range of actors in each of these sectors, and key features of their expected participation in ITS implementation.

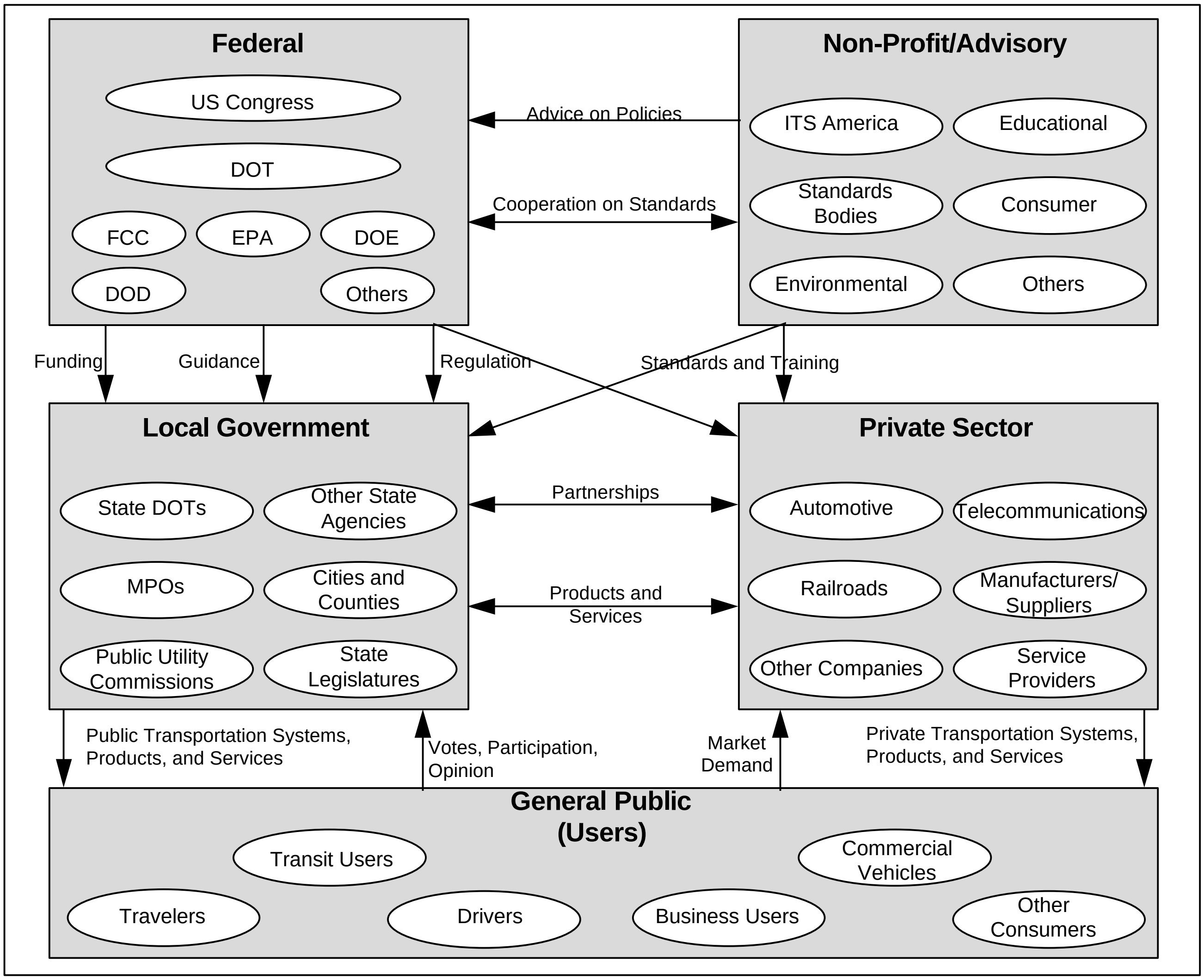


Figure 3.1-1: The Institutional Layer

3.1.1 Public Sector (and Non-profit) Involvement in ITS

In general, Congress sets the overall policy direction for the country (such as through ISTEA), determining the level of funding for transportation, programs to be emphasized, and mandates to be met. The U.S. Department of Transportation influences, interprets, and implements the legislation. The state legislature and state departments of transportation perform similar functions within the state. In some states, transportation policy and funding is also shaped by voter initiatives, which can affect the level of revenue (e.g. through bonds), and the use thereof (e.g. for transit). There are also a host of related agencies (e.g. state level air resource boards) that can provide a regulatory framework for transportation (and hence ITS) deployment.

A distinguishing feature of the surface transportation policy is the cooperative partnership between the U.S. Department of Transportation, the states, and localities. ISTEA both reinforced and, in some cases, amended this relationship. It reinforced the relationship by authorizing a variety of programs, such as the National Highway System and the IVHS Act, which reaffirmed the importance of federal leadership in select areas. It altered the relationship in a number of ways, most notably by giving additional decision-making authority to metropolitan planning organizations (MPOs) and requiring financially constrained planning efforts at both the metropolitan and state level. Consistent with this shift toward increased state and metropolitan control, ISTEA provided enhanced flexibility in the use of federal-aid funds. These trends toward local control highlight the need for the architecture to be relevant to the context of local deployment decision-making. Table 3.1-1 and Table 3.1-2 provides additional information on public sector implementors relevant to ITS; section 3.1.2. provides an exemplar focus on the role of MPO and other local actors in local deployment of ITS systems.

The "third" sector, otherwise known as the non-profit sector, plays a key role in advising the public sector, and integrating public and private sector needs. These sector includes advisory organizations (such as ITS America), standard setting bodies (such as IEEE), advocacy groups (such as environmental and consumer groups), and educational organizations. Additional information on some of the roles played by the non-profit sector is provided in Table 3.1-3.

Table 3.1-1 Federal Institutional Elements

DoT	The Department of Transportation is responsible for managing the Federal ITS program. It provides overall guidance and financial support for research, testing, deploying and evaluating ITS products and services. The modal agencies (e.g., FHWA, FTA, FRA) are responsible for administering federal-aid programs for states and localities, and for managing associated planning and reporting programs.
DoD	The Department of Defense has significant technology which may be commercialized help provide ITS services. Particular elements where these technologies are significant are in Information Management and Security, Wide Area Distributed information exchange, Communication Technologies, and In-Vehicle Sensors and Displays.
DoE	The Department of Energy conducts a wide range of technology research and development that can affect and potentially overlap with ITS developments. This includes R&D on clean cars, alternative fuels, and remote sensing devices.
EPA	The Environmental Protection Agency is responsible for enforcing federal environmental policies and regulations, including the Clean-Air Act Amendments of 1990. This Act--and the enforcement thereof--will be a key influence on the direction of ITS services in metropolitan areas. The architecture will need to facilitate a coordinated attack on complying with the EPA mandates for cleaner air and overall improved environment by merging the traffic management and emissions control activities together.
FCC	ITS services depend heavily on exchange of information and communication. These services require special coordination with Federal Communication Commission because most of the users are mobile in one way or another and will require use of spectrum. Decisions regarding special allocation of spectrum for ITS, communication security requirements, coast-to-coast interoperability of equipment, and possibly interoperability with neighboring countries require their involvement. The architecture can streamline the adoption of common communication spectrum and standards by making clear the benefits of allocating specific resources to ITS or by demonstrating the ability to utilize and possibly expand existing spectrum.

US Congress	The US Congress plays an active role in determining overall federal authorizations and appropriations for ITS. This body has major funding and legislative capabilities to make even the most difficult of ITS deployments more feasible. But they must trade-off benefits ITS with other demands of the nation and ultimately decide on the relative importance of ITS both for the nation and, in some instances, for individual localities. The architecture can both facilitate congressional action by highlighting architectural elements warranting support. A related challenge to the architecture will be its ability to accommodate early (pre-architecture) deployments that have been supported by the US Congress.

Table 3.1-2. State/Local Institutional Elements

State DoT's	Management of traffic over the nations highways involves a number of different jurisdictional entities. The state DoT's are primarily responsible for the freeway systems and state arteries which handle most of the long distance and high volume traffic. Being the backbone of the vehicular transportation system, management of these roads involves dealing with large numbers of vehicles, clearing incidents efficiently, managing congestion. Because a large amount of existing air pollution is due to vehicle emissions on freeways, the State DoT's are intimately involved with controlling these emissions.
MPOs	Recent federal legislation (i.e., ISTEA, CAAA) have strengthened the role of metropolitan planning organizations (MPOs) in developing regional transportation plans and programs. Therefore, MPOS can be expected to play a crucial role in developing regional system designs and public funding priorities for ITS. Moreover, this role places them in an important position to assist in producing the interjurisdictional agreements necessary to achieve system-wide benefits from ITS.
Counties	Because counties typically embrace areas containing both rural and urban centers, they frequently play a role in integrating transit, cities, as well as roadway maintenance for non-freeway infrastructure. A key issue for the architecture will be to ensure that it does not overburden the financial resources of these local entities. ITS can not be allowed to siphon away maintenance and operations funds from existing infrastructure but instead must be made to continue support of these areas as well as improve movement of goods through roadside inspection and dispatch emergency services to unincorporated areas.
Cities	The nation's cities are hubs for jobs and traffic, and are responsible for managing the largest transit and rail systems. The interjurisdictional issues in providing urban traffic and transit management services can be extremely complex and fragmented. The architecture needs to recognize these existing institutional complexities, and allow for early deployment under these arrangements, while at the same time encouraging institutional cooperation.
PUC's	Public Utility Commissions regulate the commercial infrastructure and need to be integrated with the ITS standards and policy making process. They can also play a role in deciding the market roles for various communication and utility providers.
State Legislators	The state legislatures currently provide significant support to evaluation and deployment of new technology for roadways and transit. Coordination of state DoT's will require support from State Legislators in terms of cooperative arrangements, legislation and funding and possibly federal fund matching.

Table 3.1-3: Non-Profit/Advisory Institutional Elements

Environmental	Environmental groups have become major stakeholders in transportation, often playing key roles in advocating for transit-friendly, multi-modal transportation policies and programs. For this reason the architecture needs to allow for different groups--such as environmental groups--to rightfully believe that transportation priorities have not been pre-empted by the architecture, but rather that the architecture can be used to implement local priorities on issues such as environmental quality.
Consumer Advocates	As ITS is intended to provide a variety of individual consumer benefits, various consumer groups (e.g. AAA, AARP),will have an interest in ensuring that the consumer is adequately represented in the architecture. The related challenge for the architecture is to ensure that consumer relevant criteria (user costs, equity, safety) are given appropriate consideration in the evaluation of architecture performance.

Educational Institutions	Educational institutions provide an important source of training for transportation professionals in both the public and private sector. Training can be as part of formal programs, such as undergraduate and graduate degrees in transportation planning and engineering. Training can also be in the form of onsite, continuing education programs specifically geared to ITS systems analysis and architecture.
Professional Societies	Professional societies play a key role in information transfer, standards setting, and education and training. As such, they will need to participate in developing the appropriate institutional and technical support for the deployment of the architecture.

Public Sector Implementor Focus: Metropolitan Decision-making

While ITS operational tests and early deployments have benefited from strong federal support, ITS deployments must be considered within the constraints of local transportation programs. In large part, this is because--ultimately--decisions about ITS deployment will have to be justified in light of potential alternative transportation uses. In some ways, the architecture could present new challenges to the process, as issues of synergies and "Intelligent Transportation Infrastructure" represent new criteria for project selection. Nonetheless, a viable implementation plan is one that can ascribe as closely as possible to the generally planning and programming process used by local transportation agencies for these processes provide the "ground rules" by which ITS systems can be expected to be judged.

Indeed, in the case studies conducted to support the implementation strategy, the local agency was found to be the key to implementation of Traffic Management and Emergency Management systems (reference appendix C). In most cases, traffic staff were the initiators. The common characteristic of the earliest implementors, such as Los Angeles, Anaheim (Orange County), and San Jose, California and in Montgomery County, Maryland, was the important role of local agency leaders in incorporating a variety of needs and possibilities into a systematic program for implementing basic ITS services.

For this reason, the deployment of National Architecture must be considered as part of the local and metropolitan planning process. As has been documented in a recent review of the regional ITS planning process (see JHK & Associates, 1996), the deployment of National Architecture needs to be viewed within the context of transportation decision-making along a variety of fronts, including: Long Range Transportation Plans, Major Transportation Investment Studies, NEPA Related Analyses, Corridor and Subarea Studies, Transportation Improvement Programs, Congestion Management Plans, Air Quality Conformance Plans.

3.1.2 Private Sector Involvement in ITS

Private sector funding and technical expertise is necessary to develop ITS technologies and to help ensure that new transportation system infrastructure is properly operated and maintained. Some of the chief reasons for encouraging private sector involvement in ITS include:

- Efficiency
- Faster service
- New sources of capital
- Generation of new income
- Shift of risk
- Market responsiveness
- Access to special knowledge and/or technology

The institutional layer highlights the role played by the various aspects of the private sector. As delineated in various ITS plans and reports, the private sector is expected to lead the development of ITS products and services. The National Architecture is explicitly geared to be responsive to private sector needs and requirements. However, unlike the legislation and practices that can aid in characterizing public sector decision-making relative to ITS, private sector decision-making is even more diffuse. ITS is envisioned to have a variety of private sector participants, from automobile manufacturers (OEMs), to telecommunications companies, to product entrepreneurs, to major trucking companies.

The private sector has established expertise in many areas including technology, traffic engineering, marketing, finance, research, and operations. It is driven to expand these areas by reinvesting revenue from product and service sales back into its business area. Revenue is sought in the consumer public and the government marketplaces. Investments in research, development, and marketing by the private sector and the costs of deploying an ITS system represent the majority of the costs of ITS. The volume sales potential of the general consumer market, if realized, can provide a large revenue source and a strong motivation for the private sector.

As delineated in Table 3.1-4, the private sector can play a variety of roles in the design and provision of ITS products and services. These diverse roles require different areas of expertise and have different profit potential.

Table 3.1-4: Varied Private Sector Roles

Role	**Functions Performed**
Service Provider	Capital Investments Consumer Responsiveness
Operator	Day to Day Management
Consultant/Systems Integrator	Design/Build
Packaged Software Provider	Develop off the shelf software serving common automation needs.
Telecommunications Provider	Telecommunications Services
Support Services Provider	Maintenance, Training, Certification
Product Developer	General Purpose and Application Unique Hardware and Software development.

The products and services that the private sector develops bring the benefits of ITS to the users of the transportation system. The private sector must always be looking to the future for new technology applications and developments in order to keep up with demand and stay ahead of the competition. The private sector must anticipate the market demand in order to be ready to supply the products and services needed. By anticipating market demand, the private sector’s role is expanded to include an ITS vision for the future. Private sector strategies and plans that are developed will influence the future of ITS.

The private sector also plays a role in the development of industry standards, that make interoperable systems possible. These industry standards are often developed from a consensus process at the Standards Developing Organizations. To the private sector, standards may enhance confidence to develop and deploy new products and services.

Tables 3.1-5 and 3.1-6 provide additional information on private sector implementors, as well as related organizational and consumer groups.

Table 3.1-5: Private Sector Institutional Elements

Auto Industry	Because a very large portion of the overall funding of ITS services is expected to be on private autos and commercial vehicles, the auto industry will play an integral part in developing technology which goes in the automobile and standards which link various equipment within the vehicles
Hi Tech Industries	New technology for better instrumentation of roadways, exchange of information, and advanced vehicle sensors and control will require development of advanced technologies. A major force in ITS will be the various communications companies which are seeking to expand their portfolio o products and services. The architecture will need to be developed cognizant of the market technology, and regulatory developments taken place in this fast growing industrial sector (which includes electronics, software, communication, and system integration firms)
System Integrators	ITS and the National Architecture imply a host of systems integration efforts at the local, regional state, and multi-state levels. System Integrators will play an important role in designing implementing, and managing integrated ITS systems.
Service Providers	There is significant new business opportunity in providing ITS services, especially the informatior dissemination services. Opportunities are also available for integrating operators, hammering ou policies, and general management of cooperative ventures.

Table 3.1-6: General Public Institutional Elements

Travelers	The architecture must deliver benefits to the travelers if it is to be a viable market-based system The deployment of the architecture will need to ensure that a range of travelers are intended beneficiaries, including drivers, transit users, bicyclists, and pedestrians.
Drivers	Although transportation policy encourages use of multiple modes of travel, the predominate form o travel continues to be automobile travel, thus making it the major market for ATIS and related services. The National Architecture will need to provide valuable services to the segment, while a the same time ensuring adequate safeguards ensuring safety while traveling.
Other Consumers	The ongoing information revolution is creating entirely new markets for information. For example media companies are considering a range of programming options for home use. National Architecture will need to be accommodative of new developments which could provide new platforms for services and products.
Commercial Users	Commercial users are vital stakeholders in ITS. Because this segment often experiences tangible (e.g., financial) gain from ITS, they provide reliable measure of the manifest demand for various services. Moreover, they represent key early beneficiaries that can aid in ensuring successful early experiences with ITS. The National Architecture will need to ensure that the needs and interests o commercials users are centrally represented in the architecture design and implementation.

Private Sector Focus: The Role of Information Service Providers

The architecture provides a framework within which ITS development and deployment can proceed with regard to both public and private sector services and products. As delineated in Section 3.2, the market packages span from those that have inherent public sector characteristics to those that have strong private sector characteristics.

The treatment of the "information service provider"(ISP) is therefore a key element in both the architecture design and implementation. ISPs are considered to be the information bundler for the various ITS information sources; while either the public sector or the private sector can fulfill the function of the ISP, clearly a strong role is envisioned for the private sector. Further, given the cost allocation breakdowns summarized in section 3.3., the implementation strategy emphasizes private sector involvement wherever possible. Various forms of public/private partnerships can serve as a bridge to encourage the private sector participation in early deployments and testing.

The information service provider is a user of each of the subsystems that collects transportation system information. This includes the Transit Management, Transit Vehicle, Traffic Management, Roadside, and Parking Management subsystems. The Information Service Provider provides the focal point for traveler information to the Vehicle Subsystems that are owned and operated by its clientele to cooperatively gather additional real-time transportation status information (through the Probe Surveillance market package). In the same way, the public agencies responsible for traffic management can use the information made available through the Information Service Provider and Personal Vehicle subsystems. In some cases, the private sector service provider may also fund additional surveillance infrastructure to become a primary agent for data collection as well as for data distribution. This expanded role is being tested in a number of different public/private partnerships in the U.S. For instance, in the city of Atlanta a private traffic information provider has funded the installation of CCTV cameras in exchange for ready access to the surveillance data provided by these cameras as well as the other surveillance infrastructure in the Atlanta area.

3.1.3 Public Private Partnerships

An important intersection between public and private sector participation in ITS implementation is the role of public/private partnerships. It is important to recognize that a partnership is more than cost sharing. It is an attitude leading to cooperation and trust and a productive working relationship with tangible benefit to each of the partners. As noted in the Figure 3.1-2, both parties bring several important attributes to the partnership; for example, the private sector brings strengths with regard to consumer understanding and awareness, whereas the public sector brings its orientation to public goals and can provide early financial support when benefits are too uncertain to attract private sector capital. As the nature of the ITS program places high value on bringing the private sector into partnerships with varied public sector agencies, there is a need to understand the interests and concerns of ITS-related industries, while at the same time ensuring the achievement of public goals. From an architecture perspective, it is important to note that the goal of the architecture would be to provide a framework which encourages appropriate private sector investment. And in this sense, public/private partnerships are implementation options to facilitate (not replace) such investments

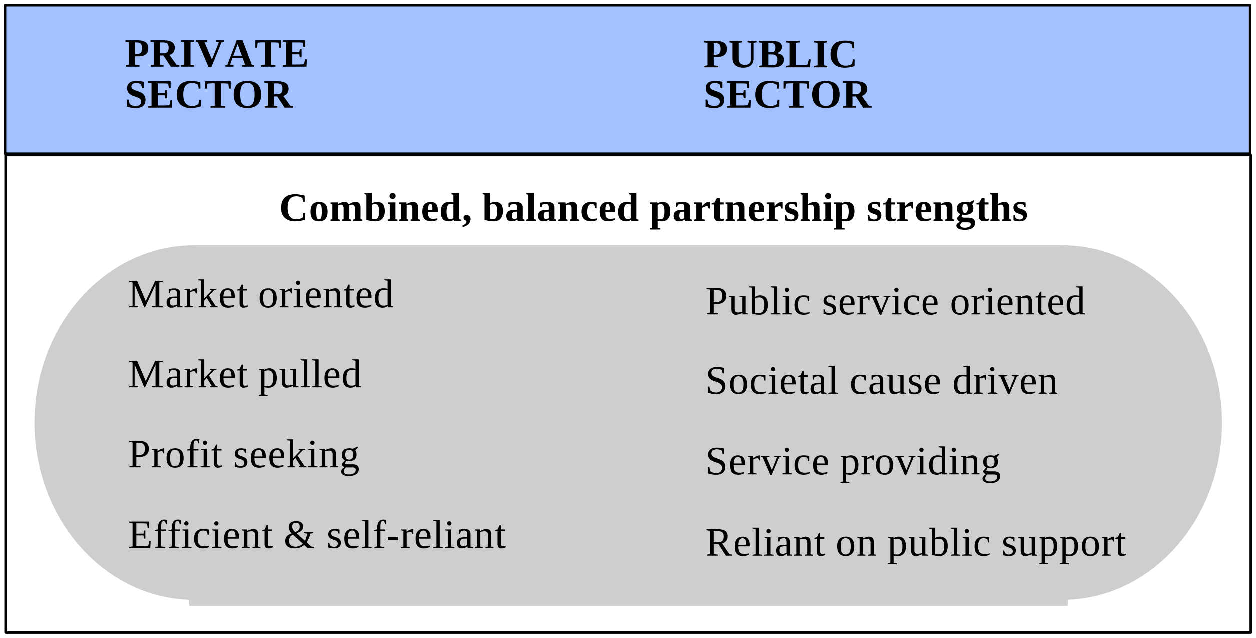


Figure 3.1-2: Combining Public and Private Sector Strengths Through Partnerships

A variety of workshops and studies have been conducted (See Public-Private Workshops in ITS: Workshop Proceedings, FHWA, 1994; ITS Shared Resources Project: Draft Report, Apogee, 1995) on public-private partnerships, and these can provide useful insight into the deployment of architecture-compatible systems. For example, a recent study on shared right-of-way resources demonstrated how local governments can cost share with the private sector to provide wireline communications infrastructures.

3.1.4 Private Versus Public Sector Participation in Market Package Deployment

The respective roles of the public sector, private sector, and public-private partnerships is perhaps best illustrated through market package analysis. Each of the market packages is assessed in this section to estimate their relative attractiveness to the private sector. This assessment results in a pivotal set of assumptions guiding the implementation strategy since it identifies those portions of the architecture that will be motivated by market forces and largely beyond the direct control of a preconceived implementation strategy. These assumptions suggest where public sector initiatives can be focused to encourage private sector participation and partnerships.

An analysis of each of the market packages with respect to the feasibility of recovery of costs through fees versus the perceived risk by investors was performed. Figure 3.1-3 is a summary of that analysis and is used to determine the level of influence by market forces where applicable. There is an assumption that the private sector is more likely to be involved if the producer/operator has the opportunity to recover costs through direct fees for the service. This scenario provides a better match between benefits and costs, and overall, ITS user services are likely to be deployed more rapidly and efficiently. Market packages that are motivated by market forces also lie beyond direct control of the implementation strategy. Market packages that provide social benefits, but are not market driven, require incentives to facilitate their deployment.

Figure 3.1-3 begins with the assumption that the private sector will be actively involved for those market packages with the largest and most certain profit potential. It further assumes that some level of additional deployment support must be provided by the public sector for the remaining market packages if they are to be deployed at all. More detailed analyses that are specifically oriented towards identifying the market packages most appropriate for partnerships are also possible. For example, the following steps could be taken:

1. Identify the market packages that provide a public good and are otherwise aligned with the public sector priorities in the region. The Performance/Benefits Study is one source of ITS benefits information that can aid in this process. The identified market packages are a natural focus for public sector deployment and form the pool of candidate market packages in the next step.
2. Identify the equipment packages that are required to support the candidate market packages. This information is available in both table 2.3-1 and Appendix A in this document.
3. Review each of these equipment packages to determine which, if any, appears to be a profitable market for a private company. Of course, this condition is only truly satisfied if there is current private sector activity in the area or if active private sector interest in a prospective product or service can be attracted and sustained.

Through this process, the market packages most likely to reward both public and private sector involvement can be identified. The identified market packages would be most appropriate for some form of public-private partnership.

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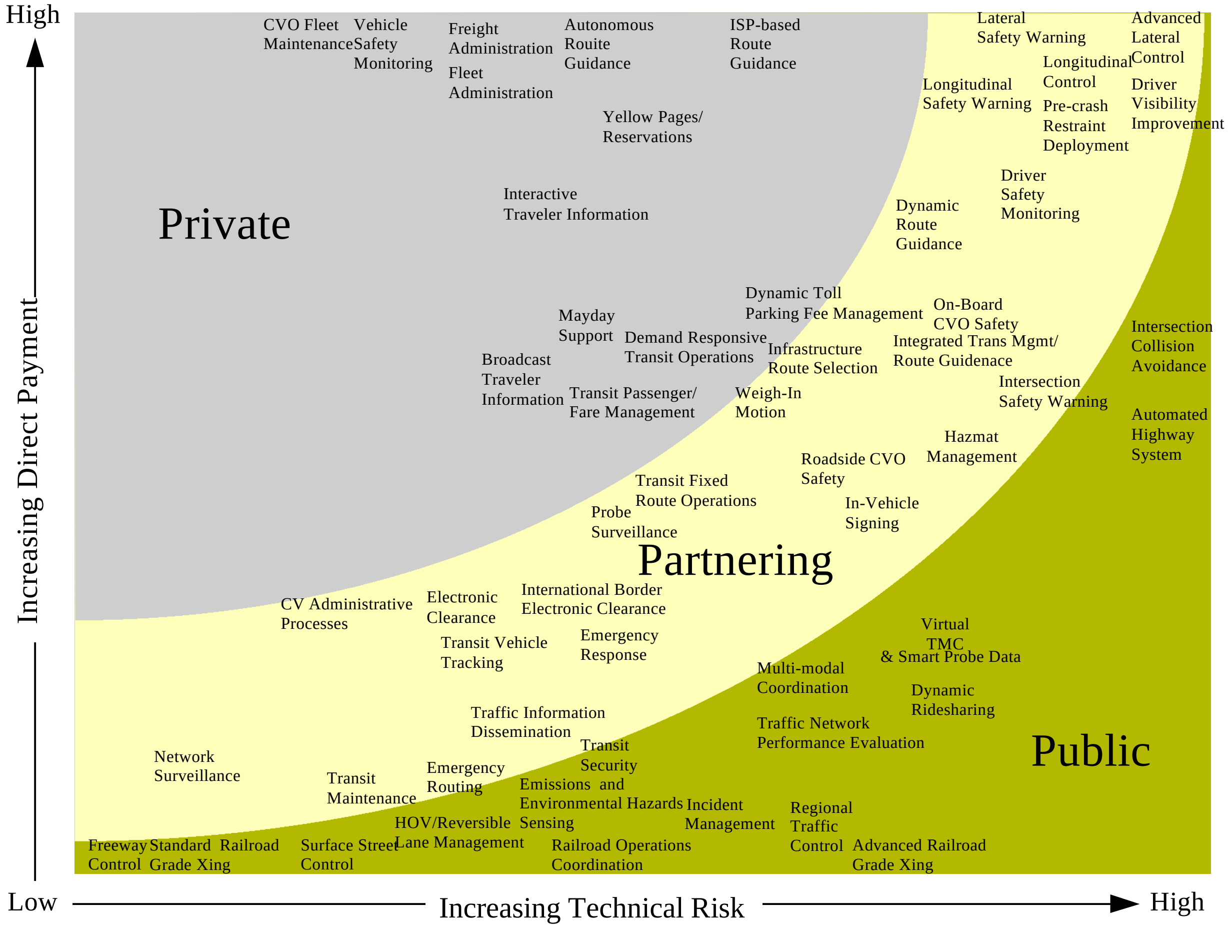

Figure 3.1-3: Market Package Risk and Cost Recovery through Fees

3.2 Identifying Producers, Operators, and Consumers

ITS implementation depends on various sectors of the national economy to produce, operate, maintain and ultimately use ITS services. Successful deployment requires participation by individuals and organizations that are motivated to provide, purchase, and use each of the necessary system elements. This section identifies the likely participants for each National Architecture subsystem.

The identified roles are not immutable, but rather, will be highly situational and vary over time. Innovative public-private partnerships, vertically integrated market initiatives, and other fresh approaches have the potential to make significant changes to the largely traditional roles that are identified in this section. Despite this potential for variation and change, this section provides a general characterization of the expected participation in ITS implementation by recognizing that implementation roles are likely to continue, at least initially, along largely traditional lines.

3.2.1 Producers

Production encompasses the portion of the product life cycle required to bring a system or component to the point where it may be purchased and used. Procurement is the milestone that separates production from operations and maintenance for purposes of this discussion. The groups that perform the production for each of the defined subsystems are identified by category in Table 3.2-1.

Table 3.2-1: ITS Subsystem Producers

Producers	Public Sector				Commercial Sector			General Public
Subsystem	Federal Agencies	State Agencies	Regional Authorities	Local Authorities	Manufacturer/ Supplier	System Integrator	Service Provider	
Commercial Vehicle Administration	**S**	**S**	**S**		**P**	**P**		
Commercial Vehicle Check	**S**	**S**	**S**		**P**	**P**		
Commercial Vehicle					**P**			
Emergency Management		**S**	**S**	**S**	**P**	**P**	**S**	
Emergency Vehicle		**S**	**S**	**S**	**P**	**P**	**S**	
Emissions Management	**S**	**S**	**S**		**P**	**P**		
Fleet and Freight Management					**P**	**P**	**S**	
Information Service Provider					**P**	**P**	**S**	
Parking Management				**S**	**P**	**P**	**S**	
Planning	**S**	**S**	**S**	**S**	**P**	**P**		
Personal Information Access					**P**			
Remote Traveler Support			**S**	**S**	**P**	**P**	**S**	
Roadway		**S**	**S**	**S**	**P**	**P**		
Toll Administration			**S**	**S**	**P**	**P**	**S**	
Toll Collection				**S**	**P**	**P**	**S**	
Traffic Management		**S**	**S**	**S**	**P**	**P**		
Transit Management			**S**	**S**	**P**	**P**	**S**	
Transit Vehicle			**S**	**S**	**P**	**P**	**S**	
Vehicle					**P**			
P: Primary Role S: Supporting Role								

The private sector plays the principal role in production of all ITS subsystems. This is the traditional approach which encourages competition with its market oriented price structures and economies of scale. Many of the subsystems defined by the architecture are themselves complex systems which may require a system integrator to “produce” a tailored solution for the system requirements; such subsystems are distinguished in the table by indicating primary production involvement from both manufacturers and system integrators. For these subsystems, the public agency or service provider that will ultimately operate and maintain the subsystem is identified as providing a supporting role in its production. This supporting role reflects those activities associated with active management of a development contract to ensure the system that is produced meets the needs of its operators. In some cases, the procuring agency may choose to utilize an in-house capability to provide the system integrator role.

Varying public sector roles are anticipated in the production of the different subsystems. The public sector role is generally limited to provision of data to encourage production and deployment of Information Service Provider, Personal Information Access, and Personal Vehicle Subsystems. Conversely, the public sector role in production for the Traffic Management, Emissions Management, and Roadway subsystems has been, and is likely to remain, very significant.

Transit agencies play a supporting role in production of the integrated transit systems supported by the Transit Management and Transit Vehicle Subsystems. These transit agencies are local or regional in the majority of cases. It is assumed that federal agencies will participate in the implementation of the Commercial Vehicle Administration and Commercial Vehicle Inspection Subsystems that support regulation and coordination from state to state and at international ports of entry. States and regional agencies will have a more substantial oversight role in the general implementation of these subsystems.

Public agencies also play a key supporting role in production of the Emergency Management and Emergency Vehicle subsystems. In this case, there are responsible organizations at the local, regional, and state levels ranging from municipal police departments to regional hazardous material response teams to state offices of emergency services. Commercial Service Providers operate private ambulance and towing companies and support production of the emergency management subsystems providing these functions.

3.2.2 Operators/Maintainers

Operation and maintenance encompass the portions of the product life from procurement through salvage. The assumed allocation of operations and maintenance responsibilities for each subsystem is identified in Table 3.2-2 below.

Table 3.2-2: ITS Operators and Maintainers

Operations/Maintenance	Public Sector				Commercial Sector			General Public
Subsystem	Federal Agencies	State Agencies	Regional Authorities	Local Authorities	Manufacturer/ Supplier	System Integrator	Service Provider	
Commercial Vehicle Administration	**O,M**	**O,M**			**M**	**M**		
Commercial Vehicle Check	**O,M**	**O,M**			**M**	**M**		
Commercial Vehicle					**M**	**M**	**O,M**	
Emergency Management		**O,M**	**O,M**	**O,M**	**M**	**M**	**O,M**	
Emergency Vehicle		**O,M**	**O,M**	**O,M**	**M**	**M**	**O,M**	
Emissions Management		**O,M**	**O,M**		**M**	**M**		
Fleet and Freight Management					**M**	**M**	**O,M**	
Information Service Provider					**M**	**M**	**O,M**	
Parking Management				**O,M**	**M**	**M**	**O,M**	
Planning	**O,M**	**O,M**	**O,M**	**O,M**	**M**	**M**		
Personal Information Access					**M**		**M**	**O**
Remote Traveler Support			**O,M**	**O,M**	**M**	**M**	**O,M**	
Roadway		**O,M**	**O,M**	**O,M**	**M**	**M**		
Toll Administration			**O,M**	**O,M**	**M**	**M**	**O,M**	
Toll Collection			**O,M**	**O,M**	**M**	**M**	**O,M**	
Traffic Management		**O,M**	**O,M**	**O,M**	**M**	**M**		
Transit Management			**O,M**	**O,M**	**M**	**M**	**O,M**	
Transit Vehicle			**O,M**	**O,M**	**M**	**M**	**O,M**	
Vehicle					**M**		**M**	**O,M**
O: Operations M: Maintenance								

The table shows a general parity in allocation of operations responsibility between the public and private sectors. In many cases, the table also shows that a given subsystem may be operated by either a public agency or commercial enterprise. These dual assignments reflect the fact that the architecture is defined in a manner that is independent of who owns, operates, and maintains a particular piece of the system. A range of scenarios are supported.

The assumptions in the table generally reflect current organizational responsibilities with some adaptation to factor in the evident trend towards privatization. The majority of the subsystems may be operated either by the public or commercial sector depending on the local situation. The subsystems which provide traffic management, commercial vehicle administration and inspection, and emissions management are assumed to remain largely within the public sector. Commercial fleets (included in the table as Service Providers) have primary responsibility for operation of the Commercial Vehicle and Fleet Management subsystems. The Information Service Provider is also specifically targeted for the commercial sector as reflected in the table. Individuals operate the Personal Vehicle and Personal Information Access subsystems. Of course, numerous counter-examples can be developed to these general assignments. In some cases, an ISP may be publicly operated. Public agencies that manage vehicle fleets will operate Fleet Management and Commercial Vehicle subsystems.

In general, those that operate a subsystem also have some responsibility for its maintenance. This is particularly true for subsystems that support large volumes of vehicles and travelers or any others for which very high system availability is instrumental. To improve response to operational problems in these subsystems, some level of service capability must reside in the operating organization. This requires that appropriate personnel, training, diagnostic equipment, and spare parts be available as a first line of defense. The commercial sector supports this maintenance through real-time technical support and provision of spare parts. The equipment manufacturer and system integrator bear responsibility for maintenance of the systems they have produced, at least through the warranty period. Increasingly, these warranties are supplemented by extended service contracts with the provider or independent service companies, a trend which is likely to continue and expand. It is assumed that the general public will rely on the commercial sector for maintenance and repair of the subsystems that it operates.

3.2.3 Users

This section identifies the users of the services that are provided by each of the subsystems. Users, in general, are defined to be those who derive benefit from the operation of the subsystem. Within this definition, there are both interim users and end users. Interim users are those public agencies or commercial enterprises that benefit from the operation of a particular subsystem because it enhances the services they provide. An example of an interim user is a traveler information provider who “uses” the Traffic Management Subsystem and Roadside Subsystem as a primary source for traffic data that is processed, enhanced, and provided as traveler information to end users. Both interim and end users are identified for each ITS subsystem in Table 3.2-3.

The columns that identify the different types of participants are modified in this table to better define the potential transportation system users. The Commercial Sector taxonomy is modified by omitting the manufacturers and integrators (who do not play a direct role in the use of transportation systems) and by further decomposing the different types of commercial service providers who do directly use ITS services. The Commercial Sector users are categorized as commercial vehicle operators, emergency vehicle operators (e.g., towing companies, private ambulance services), transportation service providers (e.g., toll road operators, paratransit fleet operators), and information providers. The general public is divided into individuals and the public at large to differentiate between subsystems that provide direct benefit to individual users and subsystems oriented towards system benefit which are “used” by the public at large.

Table 3.2-3: Subsystem Users

Users	Public Sector				Commercial Sector				General Public	
Subsystem	Federal Agencies	State Agencies	Regional Authorities	Local Authorities	Commercial Vehicle Operator	Emergency Vehicle Operator	Transportation Service Providers	Information Service Providers	Direct Users	Public-at-Large
Commercial Vehicle Administration	X	X	X		X					
Commercial Vehicle Check	X	X	X		X					
Commercial Vehicle	X	X	X		X					
Emergency Management		X	X	X		X				X
Emergency Vehicle		X	X	X		X				X
Emissions Management		X	X							X
Fleet and Freight Management	X	X	X	X	X		X			
Information Service Provider		X	X	X			X	X	X	
Parking Management			X	X			X	X	X	
Personal Information Access								X	X	
Planning	X	X	X	X						
Remote Traveler Support		X	X	X					X	
Roadway		X	X	X	X	X	X		X	X
Toll Administration		X	X	X	X		X	X	X	
Toll Collection		X	X	X	X		X		X	X
Traffic Management		X	X	X		X	X	X	X	
Transit Management			X	X			X	X	X	
Transit Vehicle			X	X			X	X	X	
Vehicle	X	X	X	X				X	X	

The matrix is densely populated based on the working definition for user and some additional assumptions. One assumption is that the operators of the various subsystems are also users since the operators should derive some benefit from the subsystem they operate. In most cases, the subsystems make operations more efficient or effective by providing better and more timely information to the system operators. Based on this assumption, every operator identified in the previous section is assumed to be an interim user in this section.

Additional users are identified whenever a subsystem, operated by one individual or organization, provides information or other services to a second individual or organization. To illustrate, the Commercial Vehicle Administration and Commercial Vehicle Inspection Subsystems are used by the Commercial Vehicle Operator to expedite operations such as purchase of credentials, payment of taxes, and roadside safety inspections. Similarly, the public agencies responsible for commercial vehicle administration and inspection use the Commercial Vehicle Operator’s Fleet Management and Commercial Vehicle subsystems to support more efficient electronic credentials transactions and more effective screening of vehicles for safety inspection.

The identification of users within the general public for each subsystem is derived from an assessment of the benefits to those users through subsystem operation. The general public derives direct benefit through individual use of a subsystem as well as system level benefits which accrue to non-users through subsystem operation. The subsystems that are identified as catering to individual users is driven largely by perception. For instance, the individual driver may receive about the same magnitude of benefit in terms of travel time savings through operation of an advanced traffic management subsystem and the operation of an ISP subsystem which provides personalized guidance. It is less likely that the individual driver will perceive an individual benefit from the traffic management subsystem even though individual benefits may be equivalent. Non-users are identified in the table where those who do not interface to the system perceive direct benefit from its operation. Only subsystems which offer first-order benefits to non-users were identified in the "non-users" column.

3.3 Who Provides the Funding

The successful deployment of the National Architecture is also based on the requirement that funding for production as well as operation and maintenance is available for the required elements of the architecture in the time frame of interest. This section identifies the groups that will most likely fund the production, operation and maintenance, and use of ITS systems. Furthermore it will identify the end users who will be paying for services delivered by ITS and how the funds are collected from them.

The argument can be made that all costs for production are ultimately paid by the users or the general public. As an example, the cost a manufacturer incurs to produce an in-vehicle system like an air bag deployment system will be recovered from users as they buy vehicles equipped with air bags. This view hides the fact that the manufacturer put a great deal of capital at risk in the development of the air bag system. The manufacturer puts its own money at risk for production of the air bag system, and the users put their money at risk at the time of purchase, when they assume financial responsibility for its operation and maintenance. Therefore, production is funded by the manufacturer, and operation and maintenance are funded by the user.

A corollary can be found in the discussion of sources of funding. Private industry will not participate where a reasonable return cannot be expected. They may, however, participate if incentives are provided by the public sector. These incentives cover a broad spectrum that can include everything from tax credits to grants. The same argument can be made for public agencies. For the purposes of this discussion, the focus will be on the point where the money is actually applied to accomplishment of the task at hand. For example, if private industry develops a sensor as part of a partnership with a regional authority, private industry would be considered responsible for the funding.

As a general rule, the basic assumption can be made that the sectors identified as performing a function in section 3.2 will be responsible for its funding. The discussions that follow indicate the cases where there is an exception to the general rule.

3.3.1 Production

Production encompasses the portion of the product life cycle required to bring the subsystem to the point where the product may be purchased and used, as discussed in section 3.1.1. The sectors responsible for funding the production of the subsystems are identified in Table 3.3-1 below. The Table provides a qualitative indication of the level of funding by each sector within the subsystems. As a general rule, entries in the Table refer to the sectors that put money at risk to bring a particular product or service to market. As an example, a transit vehicle manufacturer would fund the R&D, product development and all other activities associated with integrating in-vehicle systems into the vehicles it produced even though the costs may actually be recovered when the vehicle is sold to a Transit Service Provider.

Table 3.3-1: ITS Production Funding

	Public Sector				Commercial			General Public			
Subsystem	Federal Agencies	State Agencies	Regional Authorities	Local Authorities	Auto Industry	High Tech Industry	Service Providers	Travelers	Vehicle Owners	Commercial Users	Others
Commercial Vehicle Administration	M	M	L			L	L			M	
Commercial Vehicle Check	M	M	L			M	L			M	
Commercial Vehicle					M	H				L	
Emergency Management		M	L	M	M	M	L				
Emergency Vehicle					M	H					
Emissions Management	L	M	M	M		H	L				
Fleet and Freight Management					L	H	M			L	
Information Service Provider		L		L		H	M				
Parking Management			L	L		H	M				
Personal Information Access						H	H				
Planning	M	M	M	M		L					
Roadway	M	M	L	M		M	L				
Remote Traveler Support			L	L		M	H				
Toll Administration			L	L		H					
Toll Collection			L	L		H					
Traffic Management	M	H		H		M	L				
Transit Management	M	M		M		H	L				
Transit Vehicle				M	M	H					
Vehicle					H	H					

Legend: H-high M - medium L- low

It is expected that the Public Sector will provide some funding to programs like the TravInfo project which create regional "pools" of information for access by the private Service Providers. These Service Providers will not only fund their own systems, but they may also contribute funding to the regional information pool. There also may be cases where they pay for information or services provided by other Service Providers, such as transit managers, when these pools are not justified.

At the other end of the spectrum is the General Public, which produces a great deal of information for the Service Provider and Public Sector organizations at little or no cost as a by product of the service they receive. An example is the individual's route plan which is logged with the transportation manager as a result of the use of the route guidance market package by the private or commercial vehicle operator. The route plan can then be integrated with other plans to produce information for several transportation management planning functions such as demand management.

In the Traffic Management and Roadway subsystems, the federal agencies provide much of the funding for production, but do not actually construct transportation management systems. It is expected that federal agencies will continue to fund such projects and will continue to hold state, regional, and local agencies responsible for production. A similar federal role is likely in funding the more advanced infrastructure to support AVSS systems including the automated highway and intersection collision avoidance market packages.

From the qualitative analysis, it is clear that the private sector plays a large role in funding production of the National Architecture. From a comparison of Table 3.2-1 with Table 3.3-1, the funding level for production is higher than the level of involvement in production for some subsystems. This indicates that production would be undertaken by the private sector under contract to the public sector. In the case of subsystems with high public benefit but low market potential, private production would be subsidized by the public sector. And in particular, the public sector plays an important role in funding for key subsystems for early deployment (e.g. traffic management centers).

3.3.2 Operation/Maintenance

Operation and maintenance encompass the portions of the product life from procurement through salvage. The funding responsibilities for operations and maintenance of the subsystems are identified in Table 3.3-2 below. The Table provides a qualitative indication of the level of funding for operation/maintenance involvement of each sector within the subsystems.

Table 3.3-2: ITS Operations and Maintenance Funding

	Public Sector				Commercial			General Public			
Subsystem	Federal Agencies	State Agencies	Regional Authorities	Local Authorities	Auto Industry	High Tech Industry	Service Providers	Travelers	Private Vehicle Owners	Commercial Users	Others
Commercial Vehicle Administration	M	M				L	L			M	
Commercial Vehicle Check	M	M				L	L			M	
Commercial Vehicle						L				H	
Emergency Management		M	M	M			M				
Emergency Vehicle				H	L	L	H				
Emissions Management		H	M	L			L				
Fleet and Freight Management						L	L			H	
Information Service Provider				H		L	H				
Parking Management				H		L	H				
Personal Information Access						L	L	H			
Planning	H	H	H	H		L					
Roadway		H	H	H		L					
Remote Traveler Support			L	M		L	H				
Toll Administration			H	H		L	M				
Toll Collection			H	H		L	M				
Traffic Management				H		L	L				
Transit Management			H	H		L	H				
Transit Vehicle			H	H		L	H				
Vehicle						L			H		

Legend: H-high M - medium L- low

A High level of involvement indicates that members of the given segment are responsible for funding the operation and/or maintenance of a significant portion of many of the market packages within the subsystem, that is, budgeting the funds and channeling them to operations and maintenance. A Medium level of involvement indicates that members of the given segment are responsible for funding the operation and/or maintenance of a significant portion of few market packages within the subsystem. Finally, a Low level of involvement indicates that members of the given segment play a small part in funding the operation and/or maintenance of the market packages within the subsystem.

In several cases, both private service providers and public agencies are indicated as having a high level of involvement in operations and maintenance. This is due to the fact that both private and public entities can be the operators of such subsystems, e.g., parking management and emergency vehicle subsystems among others. The “H” indicates that the owner-operator -- whether public or private -- assumes a high level of responsibility for funding the operations and maintenance of their own mutually-exclusive subsystems, not that public and private sectors share responsibility for identical subsystem installations.

Though the maintenance of private in-vehicle systems is largely performed by the commercial sector, Private Vehicle owners will fund that function through direct payment similar to the way in-vehicle systems are maintained today, including repairs and any recurring costs. The High Tech and Auto Industries may, however, partially fund maintenance through service contracts and warrantees for correction of manufacturing problems; that is, these industries accept some of the risk and thus the costs of maintenance within stated boundaries.

The operation and maintenance of the Commercial Vehicle, Transit Vehicle, and Emergency Vehicle subsystems are funded in the same manner. Some of the larger transit, emergency, and commercial fleets may perform the maintenance in-house when they have the internal expertise, but this does not affect their responsibility for funding.

Since many of the subsystems that are operated and maintained primarily by the Private Sector and General Public rely on sharing information with the ATMS subsystem, the level of involvement for the Public Sector is more prevalent across subsystems than it would be for production.

Federal and state funds are typically not provided for local or regional operations and maintenance. In the case study agencies, operations and maintenance costs are locally funded. These costs are not insignificant. For example, in San Jose, the estimated annual operating costs are on the order of $500,000.

3.3.3 User Payments

The ability and willingness of the general public to actually foot the bill for the range of new ITS services remains an issue that will be clarified through experience with initial deployments and on-going market research.

There is a distinction between funding or financing of ITS, which indicates who underwrites development and/or delivery of services, and payment for those services. Payment refers to reimbursement for development and delivery costs initially underwritten by public and private organizations. Ultimately, the General Public pays for everything -- either directly through user fees and direct purchase of on-board or on-site equipment, or through taxes of some kind or another. For that portion of ITS services not paid through user fees and direct purchases, various public agencies act as the intermediaries which collect taxes and channel them through budgetary allocations to pay for the balance of the costs. Because direct payments and taxes are the ultimate sources of payment, this section focuses only on the General Public and public agencies as the payment sources for ITS services. That is, Private Sector companies do not "pay" for these services unless they are the final consumers, in which case they are included under commercial users in the General Public segment of this discussion. Private Sector companies are otherwise intermediaries who fund/finance development and delivery, but who are fully reimbursed by users and/or public agencies and so do not end up paying for these services.

Table 3.3-3 presents summary data on the ways in which ITS services are funded. The first segment of the table indicates how the General Public pays for ITS services and the proportion of total costs covered by direct payments; the second portion indicates the relative shares of public agencies in payment for services not fully covered by direct payment.

Table 3.3-3: ITS Service Funding

Subsystem	General Public					Public Agency			
	Sources of Payment				Proportion	Relative Level of Payment Support			
	Travelers	Private Vehicle Owner	Commercial Users	Others	Direct Payment	Federal Agencies	State Agencies	Regional Authorities	Local Authorities
Commercial Vehicle Administration	UT,GT	UT,GT	DP,UT,GT	GT	L-M	M	H		
Comm. Vehicle Check	UT,GT	UT,GT	DP,UT,GT	GT	L-M	M	H		
Commercial Vehicle			DP		H	L			
Emergency Management	DP,UT,GT	DP,UT,GT	DP,UT,GT	DP,UT,GT	L		M	M	H
Emissions Management	GT	DP,UT,GT	DP,UT,GT	GT	L		M-H	L	L
Emergency Vehicle	DP,UT,GT	DP,UT,GT	DP,UT,GT	DP,UT,GT	L-M			M	H
Fleet and Freight Management			DP		H	L	L	L	L
Info Service Provider	DP,UT,GT	DP,UT,GT	GT	DP,UT,GT	M-H			M	M
Personal Info Access	DP	DP	DP		H				
Parking Management		DP,UT,GT	DP,UT,GT	GT	L-M			M	M-H
Planning	UT,GT	UT,GT	UT,GT	UT,GT	-			H	H
Roadway	DP,UT,GT	DP,UT,GT	DP,UT,GT	GT	L-M	L	M	M	H
Remote Traveler Support	DP,UT,GT	DP,UT,GT	DP,UT,GT	UT,GT	M-H		L-M	L	M
Toll Administration	DP,UT,GT	DP,UT,GT	DP,UT,GT	GT	L-M			M	M
Toll Collection	DP,UT,GT	DP,UT,GT	DP,UT,GT	GT	M-H			M	M
Traffic Management	DP,UT,GT	DP,UT,GT	UT,GT	UT,GT	L			H	H
Transit Management	DP,UT,GT	UT,GT	UT,GT	UT,GT	L	L		H	H
Transit Vehicle	DP,UT,GT	UT,GT	UT,GT	UT,GT	L	L		H	H
Vehicle		DP	DP		H				

DP = Direct Payment, GT = General Taxes, UT = User Taxes (fuel, transportation ticket, registration), L=Low, M=Medium, H=High
Federal = Primarily Highway Trust Fund; State, Regional, Local = all other sources, including debt and pay-as-you-go structures

The "Other" column of the General Public section of the table refers to all those not traveling. At some time, everyone falls into this category and, through taxes paid and government budgetary allocations, helps pay for ITS services. For example, if a public agency pays for congestion management in the interests of environmental improvement and uses a portion of county income tax revenues for this, then "Others" pay for ATMS through general taxes. Most of the General Public will belong to and pay for ITS through more than one group (column) in the table. Commercial vehicle owners will pay directly for CVO services as businessmen, through fuel taxes and income taxes paid by their business; they will also pay as private vehicle owners. And, they will help pay for these and other services through their tax payments. It should be noted that user taxes are not the same as user fees since they are not paid at the time of service nor are they necessarily paid in proportion to service use.[1]

Because only a few subsystems are fully commercialized with direct payments covering all costs (private and commercial vehicle, freight and fleet management, and personal information access), general taxes and user taxes are included as sources of payment for almost all subsystems. Even CVO includes such taxes since it is likely that at least some portion of commercial vehicle ITS services is paid with fuel tax revenues or other state-based taxes, particularly those activities in the public interest such as administration and safety-oriented tasks.

Although fleet and freight management will have a public sector content funded with tax revenues, to the extent that ITS is implemented for management of public sector vehicles such as police and maintenance fleets, these are treated as User Payments since the public sector is acting as a full-paying customer providing services for its own operations rather than underwriting ITS for other General Public or Commercial users.

The important factors to note are the situations in which direct payment (DP) is a source, indicating which segment of the general population pays on a fee-for-service or direct purchase basis, and the relative proportion of each subsystem that is paid for directly by beneficiaries. Commercial users pay directly for at least a portion of all subsystems except traffic management, which they do not utilize directly, and transit management and transit vehicles. Travelers pay user fees for information, and even for some aspects of traffic management (e.g., as passengers in a fee-for-entry HOV system). Similarly, private vehicles pay user fees for information and for portions of ATMS, though not for services they do not directly use such as those related to transit and commercial vehicle operations.

Although emergency services are often thought of as a public responsibility, fees can be collected from direct users much as private ambulances charge for their services. Thus, emergency management and vehicles can be paid at least in part through direct payments by all segments of the General Public. For example, fees can be collected not only for ambulance service but also as an EM fee attached to Mayday connections and tow-truck response.

Of greater importance perhaps is the relative proportion of costs that are reimbursed through direct user fees and payments (the fifth column of the table) and, its obverse, the proportion

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[1] In fact, user taxes are a short-hand term for all transportation taxes, some of which may be used to pay for other transportation services, and non-transportation user taxes such as entertainment, hotel, and ticket taxes. For example, fuel taxes are user taxes for road and highway vehicles but these users also help pay for transit. Thus the UT under transit includes transit-based taxes but may also include non-transit user taxes such as the fuel tax.

supported through taxes. Moreover, it is instructive to note which level of government and which public agencies are expected to shoulder the greater proportion of the public sector's burden (the last four columns).

As might be expected, the proportion of costs reimbursed from fees for EM and vehicle subsystems is low. Emergency service is traditionally public and, although fees can be collected and some vehicles could be financed through local fund-raisers and private donations, it is unlikely that these will constitute a large portion of the budget for ITS support for emergency services. (A notable exception to this general allocation is the strong role played by the private and non-profit sector [such as AAA] in providing emergency roadside service.) In general, the local authorities will bear the highest level of responsibility among public sector entities. Regional authorities will be involved to a lesser degree, with some support from state agencies such as along state and federal highways. The federal government will only be involved in developing such systems in the early stages of deployment (for example, FHWA support for early deployment plans) but not on an on-going basis.

Private transit operators and taxi fleets will pay out of fee revenues for their ITS systems and private contractors performing services such as maintenance for public transit agencies will pay directly for ITS services that help them perform their contracted tasks. Moreover, public transit passengers may pay directly for some aspects of transit management and vehicle subsystems, for example, paying a slight premium on fares to cover the costs of Smart Cards that can be used on several transit systems and/or purchasing hand-held security devices that interact with system-wide monitoring systems. Overall, however, in light of the financial difficulties already facing public transit systems, the proportion of APTS costs covered by direct payment and fees from transit riders is likely to be very low and the bulk of the costs will be covered directly or indirectly by tax revenues transferred to public transit authorities as part of their general operating and capital budgets.

When subsidies and public moneys are involved for transit, it is the regional and local authorities that are expected to be most involved. Local sales taxes, income taxes, and even local user-type taxes such as sports ticket taxes and hotel taxes will help support ITS services. Some municipalities may choose to levy user-type taxes on indirect beneficiaries, such as commercial establishments in office and industrial parks and merchants with direct access to transit stations, to pay for transit security and management since transit effectiveness has secondary benefits for these businesses.

The commercial vehicle operators will pay the bulk of CVO subsystem costs. The public sector payments will be limited to support for safety and administrative subsystems of ITS, paid from general tax revenues and user (fuel) taxes channeled through state agencies responsible for commercial vehicle registration and inspection. Federal agencies will support these efforts with funds allocated from the highway trust fund to state agencies.

Traveler Information Services comprise both traffic-oriented components geared to vehicular travelers and service-oriented components geared to all travelers. The various traffic-oriented subsystems generate benefits for their direct users, who are better able to plan and execute their trips, and for non-users through environmental impacts and through less congested roadways when users decide to alter their plans. Direct users in all three categories (travelers, private vehicles, and commercial vehicles) will pay for the better portion of the cost of these services through direct payments for equipment and service fees, although some basic services (e.g., HAR and VMS) will be offered without fee by public agencies. Nonetheless, even broadcast traveler information can collect fees if messages are coded, requiring payments for decoding. Certainly, direct users of a cell-based system will be assessed subscription/access fees and on-line fees according to the number of uses and/or time used. Similarly, home and office users can be charged for telephone access, or business establishments can pay for access for their employees.

Kiosks (represented in the architecture as Remote Traveler Support subsystems) in public places such as major office buildings, museums, parks and arenas can provide traffic as well as traveler information at no cost to the traveler, paid by public funds, or can charge nominal fees for access -- for example, operating like a pay phone with a coin-operated system. These systems can also be sponsored by their host location, e.g., a major employer, hotel, airport terminal, or hotel which pay for the receiving equipment and even for the data provided (information service provider subsystem).

For that portion of costs not covered by fees, it seems logical that state, regional and local authorities all share responsibility depending on the location and orientation of the ATIS system and parts. For example, state agencies are likely to underwrite kiosks along state and federal highways, particularly those catering to out-of-state tourists. On the other hand, it would be likely that local and regional agencies support ATIS for local residents interested in information for work commutes. Traveler services and entertainment information (i.e., remote traveler support subsystems) can be supported with local general funds, direct user fees, listing fees collected from entertainment-oriented businesses, and even some user-type taxes such as sports, movie and hotel taxes.

The Traffic Management services encompass activities that are generally considered functions of local, regional, and state government departments of transportation. As such, they affect the general traveling public. Those in private and commercial vehicles (both drivers and passengers) directly benefit from improved traffic flow; travelers in transit benefit if they use over-the-road buses (as opposed to rail). And non-travelers benefit from cleaner air, less public expenditure on road widening, etc.

Yet there are limited ways in which to assess beneficiaries directly. Fees can be charged for access to HOV lanes to cover HOV monitoring and construction, tolls collected at toll plazas will cover road use and the ITS system which allows electronic payment, and demand management can be covered out of the time-of-day and congestion-based fees assessed. However, these will constitute only a limited portion of funding necessary to support the roadway and traffic management subsystems. Thus the proportion of total ATMS-oriented subsystems that are covered by direct payment probably will be low, particularly in the early years of deployment. In later years, the proportion of user payment for services may increase as some ATMS costs such as for the roadway subsystem (information collection) are shifted to ATIS users, that is, private information service providers pay TMCs and other public agencies to purchase information collected under their auspices.

The personal vehicle subsystem and commercial vehicle subsystem components will, as they are introduced, be part of user-provided capital equipment. Public support is limited to research/development and demonstration projects under federal auspices. Otherwise, other travelers and the rest of the General Public will support roadway collision-avoidance only through taxes that pay for road-based infrastructure that trigger alarms and corrective actions in vehicles. Among the public agencies involved in infrastructure support for advanced vehicle systems, it is expected that local authorities and state DOTs will share the bulk of the costs for installing appropriate sensing devices on local and state roadways and intersections; the federal government will be involved via the Highway Trust Fund.

3.4 Institutional Issues Affecting Deployment

Given the wide range of implementors involved in deploying ITS systems, there are a number of institutional constraints that can inhibit deployment. Potential constraints include first user benefits, cost/benefit allocations, energy and environmental impacts, interjurisdictional issues, liability, antitrust, patents, privacy, standards, education and staffing, and regulatory constraints. This section describes and assesses these non-technical issues of the National Architecture, as well as one additional potential constraint (budgetary instability). A set of non-technical, socio-economic problems are identified, analyzed, and evaluated in terms of how they affect (or are affected by) the architecture, and the extent to which they have or can be mitigated either through the architecture design, or through the implementation strategy. Recommendations or mitigations are suggested to facilitate timely, least risky, and progressive ITS system development and deployment.

Table 3.4-1 provides an overview of these relationships, highlighting those market packages most affected by the associated non-technical constraint. The nature of these influences is described in each non-technical section following the table. No attempt has been made here to comprehensively present each general issue, as there are a host of reports that already do so, including both the national and local levels.[2] Rather than repeating these reviews, the focus is the issues' relevance to the National Architecture.

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[2] See FHWA *Non-technical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems*. Washington, D.C.: U.S. Department of Transpiration. See also Horan, T, *Institutional and Policy Challenges to the Deployment of ITS/ATS in California*, Berkeley, CA: California PATH Program, June, 1995).

Table 3.4-1: Institutional Implications for Defined Market Packages

Market Packages		**Institutional Issues**										
		First User Benefits	Cost/Benefit Allocations	Environment/ Energy Impacts	Interjurisdictional Issues	Liability	Antitrust	Patents	Privacy	Education and Staffing	Regulatory Constraints	Budget Instability
APTS	Transit Vehicle Tracking		■									■
	Transit Fixed-Route Operations		■	❑						■		■
	Demand Response Operations	❑		❑						■	■	■❑
	Transit Passenger and Fare Mgmt	❑			■							■
	Transit Security	❑				❑			■			■
	Transit Maintenance									■		■
	Multi-modal Coordination			❑	■					■	❑	■
ATIS	Broadcast Traveler Information	❑	❑	❑								
	Interactive Traveler Information	❑	■	❑								
	Autonomous Route Guidance	❑	❑	■❑		■						
	Dynamic Route Guidance	❑	■	■❑	■	■						
	ISP-Based Route Guidance	❑	■	■❑	■	■			■	■		
	Integrated TM/Route Guidance			■❑	■				■	■		■
	Yellow Pages & Reservation											
	Dynamic Ridesharing			❑					■	■	❑	■
	In Vehicle Signing					■					■	■
ATMS	Network Surveillance									■		■
	Probe Surveillance								■			■
	Surface Street Control	❑		■❑	■					■		■
	Freeway Control	❑		■❑	■					■		■
	HOV and Reversible Lane Mgmt			❑	■					■		■
	Traffic Information Dissemination			❑						■		■
	Regional Traffic Control	❑		■❑	■					■		■
	Incident Management System	❑		❑	■					■		■
	Traffic Network Performance Eval				■					■		
	Dynamic Toll/Parking Fee Mgmt	■❑		❑	■				■	■	■	❑
	Emissions and Enironmental Haz.			❑	■					■	❑	■
	Virtual TMC and Smart Probes								■	■		■❑
	Standard Railroad Grade Xing				■	■				■		■
	Advanced Railroad Grade Crossing				■	■				■		■
	Railroad Operations Coordination			■❑	■					■		
AVSS	Vehicle Safety Monitoring					❑		❑			■❑	
	Driver Safety Monitoring					❑		❑	■		■❑	
	Longitudinal Safety Warning							❑			■❑	
	Lateral Safety Warning							❑			■❑	
	Intersection Safety Warning				■			❑			■❑	
	Pre-Crash Restraint Deployment							❑			■❑	
	Driver Visibility Improvement					■		❑				
	Advanced Vehicle Longitudinal Ctrl		■			■		■❑		■	■	
	Advanced Vehicle Lateral Control		■			■		■❑		■	■	
	Intersection Collision Avoidance		■		■	■		■❑		■	■	■
	Automated Highway System		■	■❑	■	■	■❑	■❑	■	■	■	■
CVO	Fleet Administration		■						■			
	Freight Administration		■						■			
	Electronic Clearance	❑	■❑	❑	■				■	■	■❑	■
	CV Administrative Processes	❑	■❑	❑	■				■	■	■❑	■
	International Border Clearance		■❑		■						■❑	■
	Weigh-In-Motion	❑	■❑		■				■		■❑	
	Roadside CVO Safety				■					■	■❑	
	On-board CVO Safety										■❑	
	CVO Fleet Maintenance											
	Hazmat Management			❑	■					■	❑	■
EM	Emergency Response	■	❑		■					■		
	Emergency Routing				■							
	Mayday Support	❑			■					■		
	ITS Planning			❑	■					■	❑	■

❑ positive impact ■❑ positive or negative impact ■ negative impact

3.4.1 First User Benefits

The provision of early benefits is central to the success of ITS, and therefore needs to be a major consideration in an implementation strategy. Information on benefits must be forecast so that benefit to cost ratios or other measures that allow implementors to justify investments in ITS can be derived. Ultimately, this is as true for the end user (who performs a personal assessment for each purchase) as it is for a public institution that must formally justify use of public funds for ITS deployments.

Architecture Assessment

Benefits and transportation improvements accrue through the addition of new functionality or improvements over that offered by the already-in-place systems. The National Architecture supports the efficient provision of such benefits, both through its definition and use of market packages and because it has been designed to encourage modularity in conforming systems. Market packages describe ways in which modular deployment of ITS systems can occur in a manner linked to specific user benefits. This modular approach facilitates early ITS implementations that take advantage of in-place systems and later serve as a basis for more advanced implementations.

Deployment Implications

The actual mechanism for ensuring such early benefits is the implementation strategy. The strategy places a high priority on deploying those market packages associated with early user and system benefits. Table 3.4-2 associates the market packages with the ITS benefits; The following discussion provides an overview of how these goals can be achieved through various market package deployments, and in particular, which packages could provide early benefits in these areas.

Increase Transportation System Efficiency: This refers to movement of greater numbers of travelers throughout the transportation network without building additional physical infrastructure. The indicated market packages, which increase the effective capacity of existing roads, provide an attractive alternative to new construction. Many of these same packages are actively being deployed today providing early system benefits as summarized in table 3.4-2.

Improve Mobility: An improvement in traveler mobility is defined as the greater reliability in travel times experienced by the individual traveler. More reliable travel times result in higher-value trip end opportunities. This goal applies to congested areas which wish to influence both demand and capacity to improve mobility for individuals and goods through more efficient use of the overall transportation system. Those market packages identified as strongly correlated with this goal provide service enhancements and better information regarding these improved services.

Table 3.4-2: Anticipated Market Package Benefits

Market Packages		**ITS System Goals**					
		Increase Transportation System Efficiency	Improve Mobility	Reduce Fuel Consumption and Environmental Cost	Improve Safety	Increase Economic Productivity	Create an Environment for an ITS Market
A P T S	Transit Vehicle Tracking	*	**	*		*	*
	Fixed-Route Operations	*	**	*		*	*
	Demand-Responsive Operations	*	**	*		*	*
	Passenger and Fare Management					**	*
	Transit Security				**		*
	Transit Maintenance					*	*
	Multi-modal Coordination	*	*			*	
A T I S	Broadcast Traveler Info	*	**	*			***
	Interactive Traveler Info	**	***	*			***
	Autonomous Route Guidance	**	***				***
	Dynamic Route Guidance	**	***	*	*		***
	ISP-Based Route Guidance	**	***	*	*		***
	Integrated Transp. Mgmt/Route Guidance	***	***	**	*		**
	Yellow Pages and Reservation		*				**
	Dynamic Ridesharing	**	*	*			*
	In Vehicle Signing		*		*		***
A T M S	Network Surveillance	*	*	*			*
	Probe Surveillance	*	*	*			**
	Surface Street Control	**	***	**	**		*
	Freeway Control	**	***	**	*		*
	Regional Traffic Control	***	***	***	**		*
	HOV and Reversible Lane Management	*	**	*			*
	Incident Management System	**	**	***	**		*
	Traffic Information Dissemination	**	*	*			*
	Traffic Network Performance Evaluation	**	**				*
	Dynamic Toll / Parking Fee Management					**	*
	Emissions and Environ. Hazards Sensing			***			**
	Virtual TMC and Smart Probe Data	*	*	*		*	*
	Standard Railroad Grade Crossing				***		*
	Advanced Railroad Grade Crossing				***		*
	Railroad Operations Coordination	*	*	*			*
C V O	Fleet Administration		***			***	**
	Freight Administration		***			***	**
	Electronic Clearance	**	***			***	**
	CV Administrative Processes					**	*
	International Border Electronic Clearance	**	***			***	**
	Weigh-In-Motion	**	***			***	**
	CVO Fleet Maintenance	*			**	**	*
	HAZMAT Management	*			**	**	*
	Roadside CVO Safety	*	**		**	**	**
	On-board CVO Safety				***	**	**
A V S S	Vehicle Safety Monitoring				***		***
	Driver Safety Monitoring				***		***
	Longitudinal Safety Warning				***		***
	Lateral Safety Warning				***		***
	Intersection Safety Warning				***		***
	Pre-Crash Restraint Deployment				***		***
	Driver Visibility Improvement				***		***
	Advanced Vehicle Longitudinal Control	**	*		***		***
	Advanced Vehicle Lateral Control	**	*		***		***
	Intersection Collision Avoidance				***		***
	Automated Highway System	***	***		***		***
E M	Emergency Response	*		*	***	**	*
	Emergency Routing	*		*	***	**	*
	Mayday Support				***	*	**
	ITS Planning	**	**	**	**	**	***

Reduce Fuel Consumption and Environmental Cost: This refers to potential reduction in harmful emissions that result from vehicle use. Strongly correlated market packages smooth traffic flow resulting in higher average network speeds and fewer stops which suggests reductions in fuel usage and emissions. The Demand Management and HOV Management packages allow proactive response to any induced demand which might negate network performance improvements. Public transit packages are also included to optimize transit performance which may induce (unquantified) demand shifts to favor more environmentally friendly travel modes. Basic Traffic Management and Traveler Information market packages which smooth traffic flow and provide better information to travelers provide early system benefits as highlighted in table 3.4-2.

Improve Safety: This refers to enhanced safety that a traveler would experience while traveling throughout the transportation network due to improvements in safety equipment, and faster emergency detection and response times. However, only a subset of these safety-enhancing services will be available or partially available in the near term. This smaller set provides safety benefits to early or first users of ITS technologies. ITS services that will provide early safety benefits include Standard Railroad Grade Crossing, Transit Security, and Mayday Support.

Increase Economic Productivity: This is a universal goal that may be particularly attractive to the individuals, public agencies, and private agencies who closely equate transportation efficiency with business performance. Achieving this goal through the market packages involves providing individuals as well as public and private agencies with a more efficient and cost-effective means of doing business. Selected market packages automate financial transactions, enhance management and maintenance of commercial, transit, and emergency fleets, and facilitate the movement of goods. Basic commercial vehicle market packages provide the early user and system benefits in this area.

Create an Environment for an ITS Market This goal directly affects the characteristics of the physical architecture and its deployment; however, it does not closely correlate with individual market packages. Each of the market packages, since they embody new goods and services, are likely to encourage industry assuming the markets are viable. The differentiation in table 3.4-2 is based on potential market size; the vehicle products market served by the ATIS and AVSS market packages is larger than the ATMS infrastructure products and APTS markets. The success of new industries supporting ITS depends on an open architecture and a non-restrictive deployment strategy to encourage participation and innovation.

3.4.2 Cost-Benefit Allocations

The primary focus of examining the benefit and cost allocations is to help determine if ITS implementations will provide for an equitable distribution of costs and benefits such that no sector is unduly burdened, and most individual benefits are reaped in proportion to payment.

Architecture Assessment

By relying on existing and emerging infrastructures to the maximum extent possible, the proposed architecture ensures the maximum marginal benefits per ITS cost expended. The design of the market packages facilitates associating costs of the market packages to the beneficiaries of those costs. Further, the architecture provides a range of options, from low cost--moderate benefit, to high cost--high benefit, thus providing a range of options for users.

In terms of allocations between public and private sectors, the architecture adheres to the general institutional arrangements that surround transportation and communications infrastructure and thereby imposes no major shifts in allocation of costs between the consumer and the public sector. For example, many of the high-end traveler information functions are allocated to the vehicle, in keeping with the principle that these features should be the domain of consumer purchasing decisions, rather than considered an element of the public infrastructure.

The allocation of market packages between the public and private sectors has corresponding implications on the allocation of benefits across various users. The designation of market packages provides different gradations of functionality, from low end to high end. In addition to the aforementioned early beneficiaries, low end functionality ensures that ITS benefits are available to a wide spectrum of users: from low-income users to high income users, from large cities to small towns.

In most cases, individual benefits are reaped in proportion to payment. However some user services provide examples of public goods where the cost to the individual is low but individuals who do not pay cannot be excluded from the benefits. The majority of these services are public transit related services or demand management tools. Examples of this phenomenon include dynamic ridesharing, public transportation management, personalized public transit, public travel security, and emergency vehicle management. In each of these cases, the individual pays a very low direct cost for these services but receives a relatively large portion of the benefits.

Deployment Implications

The implementation strategy supports the equitable allocation of costs and benefits by focusing public investment on basic market packages that provide the widest benefits. Early attention is placed on basic traffic and transit management and information services in urban areas, and commercial and safety provisions (e.g. Mayday) in rural areas. Moreover, as the deployment is predicated on existing and emerging infrastructures, the costs per user are lower than would otherwise be the case. For example, in the area of traffic information, the use of the cell-based infrastructure makes information readily available through existing communications services, rather than introducing an entirely new infrastructure that would have to initiate an entirely new market.

There are a host of market packages associated with the equity issue, particularly those with significant public/private partnerships (e.g. ISP-Based Route Guidance). The core concern across these market packages is that public funds not be used to unduly benefit a small segment of society that can afford the service. This concern is mitigated by focusing the implementation strategy (and related federal investment), on those market packages that would provide the widest benefit to consumers and users, including the provision of basic safety.

3.4.3 Environment / Energy Impacts

A major goal of contemporary transportation policy--as exemplified by provisions in both the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act Amendments of 1990 (CAAA)--is to deploy transportation systems which minimize adverse environmental impacts, and where possible, promote environmental gain. The National Architecture offers the full array of ITS user services aimed at reducing transportation energy consumption, pollution emissions and traffic congestion. These range from inducing travel by alternative modes to transportation demand and system management strategies. The National Architecture strives to attain maximum benefits by allowing full integration of the ITS user services, while at the same time placing the policy decisions associated with these services at the local level.

Architecture Assessment

The National Architecture has several features that can aid in designing ITS systems to achieve environmental and energy goals. First, the ITS Planning market package can be used by regional planners to link ITS systems planning with other transportation and air quality planning. Second, the Early Market Packages provide backbone systems that can be integrated into regional plans and --as part of this larger package--assessed for conformance with air quality goals. Third, the architecture supports a number of services (e.g., emissions management, HOV management, toll management) specifically geared to the types of improvements typically considered by non-attainment areas. The architecture can readily be enhanced to incorporate additional environmentally sensitive user services as they are identified. For example, in addition to remote emissions sensing, on board sensing and reporting of emissions and energy usage could become feasible in the future. The integration of these vehicle-based systems could represent a new wave of clean car technology which the National Architecture could be enhanced to accommodate.

Deployment Implications

The implementation strategy encourages the early application of ITS for air quality and related environmental purposes. The rationale for this support is straightforward: with close to 100 of the nation's metropolitan areas struggling to achieve the gains mandated in the CAAA, ITS must address these issues if it is to be relevant to the public decisions confronting most of the metropolitan areas in the country. There are two mechanisms for supporting this application: guidance and financial aid. Strategic policy guidance could be provided for deploying ITS in non-attainment areas; such guidance would assist regions' in selecting market packages attuned to their specific attainment policies. In terms of financial incentives, funds for deploying clean air strategies (such as the CMAQ program) could be considered for ITS deployment in non-attainment areas. Specific market packages oriented towards these goals are identified in table

3.4-1. As has been pointed out by numerous environmental analysts, the actual environmental impacts achieved will be highly dependent on how local regions apply the architecture to their needs (see Hennessey and Horan, 1995).

3.4.4 Inter-jurisdictional Disputes & Local Government Coordination

According to the 1992 ITS America Strategic Plan, certain architectures will be superior to others because of their "institutional implications." This emphasis on the institutional implications is justified. The institutional framework of the deployment strategy is pivotal to successful *regional* deployment because, as the Strategic Plan indicates, "Most institutional issues arise from the integration of different components of the transportation system into a single [super] system. That interconnection of parts requires the interconnection of the institutions associated with those parts."

The National Architecture explicitly recognizes the importance and the challenge of these issues. The implication of this is two fold: 1) in a manner similar to the reliance on existing and emerging infrastructures, the implementation strategy relies on existing and emerging institutional structures for the delivery of ITS products and services, and 2) by doing so, the approach acknowledges the challenge of achieving institutional support and coordination for an open architecture.

Architecture Assessment

Many of interjuridictional constraints are uniquely associated with the broad integration of transportation systems enabled by the architecture. In particular, the issue of interjurisdictional coordination (on the pubic sector side) and standards (on the private sector side) are two key challenges to the distributed open systems approach inherent in the National Architecture. Regarding the former, the use of open systems will facilitate interjurisdictional coordination. The National Architecture promotes the use of open systems, thereby reducing interjurisdictional concerns. Standard interfaces would be utilized across jurisdictions to assure effective coordination of services and system redundancy. Obviously, such coordination will require interjurisdictional agreements regarding the deployment and operation of these facilities and related infrastructure. In many cases, these intergovernmental agreements already exist. For example; in Michigan, mechanisms have already been established to define the way governments interact. Most metropolitan areas already have at least some degree of interjurisdictional coordination of traffic management; the architecture provides an input towards developing arrangements among ITS participants.

Standards are also key to achieving seamless services and providing equal opportunity to the private sector. The approach to standards is briefly addressed in Sections 2.6 and 5.1 and is more fully developed in the companion Standards Development Plan and Standards Requirements Document deliverables.

Deployment Implications

The implementation of ITS will need to address the major institutional challenges associated with the National Architecture. These include the issues of institutional cooperation, funding and budget stability, and system integration challenges. The principal effort to mitigate these risks is to minimize the extent to which early deployment requires new levels of institutional cooperation while at the same time creating incentives for achieving such cooperation over time.

While the need for public sector cooperation pervades ITS, in the near term it is most acute for the ATMS services, as they provide much of the sensing and traffic management information utilized by many of the other market packages (see Section 2.4). Consequently, a key aspect of the implementation strategy is to ensure the timely implementation of area-wide traffic management systems; this can be done through technical guidance, and financial incentives for timely implementation. Other market packages which could warrant similar treatment include Emergency Response, Passenger and Fare Management, and Electronic Clearance; all of these can produce early benefits but entail significant institutional cooperation for these benefits to occur.

Interjurisdictional coordination will serve to encourage--where appropriate--the establishment of a region-wide organization comprised of members of the transportation community and independent service providers. Public transportation interests must be represented to assure that intermodal interests are included. Metropolitan Planning Organizations (MPO) or a similar organization dedicated to the management of ITS deployment and operations could fulfill the function of interjurisdictional coordination.

The need for public-private sector cooperation is, in the long run, the most significant challenge facing ITS. The AVSS market packages, for example, require unprecedented changes in the automobile to achieve system goals. In the near to mid-term, the ATIS and CVO market bundles will be heavily dependent on private sector participation. The ATMS market packages that improve highway-rail intersections rely on close coordination between the state and local agencies which manage the highways and the railroad industry. From a deployment strategy perspective, the process by which regions' devise implementation plans will serve as an important opportunity to develop inter-jurisdictional and public/private agreements. These partnerships can be encouraged by an implementation strategy which provides guidance on partnerships to localities and to develop open standards approaches which will encourage private sector participation.

3.4.5 Liability and Related Legal Issues

The National Architecture is designed to take into account the manifold legal issues inherent in any effort to manage the implementation of transportation technologies involving numerous public and private organizations. Most of these legal issues fall under the broad categories of liability, privacy, antitrust, inter-jurisdictional cooperation and intellectual property: These laws have rarely been applied to the particular technologies and configurations envisioned in the ITS architecture, but they have been applied in other situations that are not conceptually distinguishable.

The National Architecture can be designed to reflect these applications and, therefore, simply follow the decisions embodied in existing law (e.g. antitrust law). In some situations, existing law is less clear in its mandates for the architecture; it merely defines limits on discretion to make policy in a particular area, leaving a wide gambit to central and local planners (e.g., some privacy issues). In some situations, existing law, combined with the need for acceptance of the technology by the public and by investors, militates against a technologically feasible architecture design (e.g., liability issues in connection with automated highway systems).

In general, the National Architecture imposes no major shifts in legal responsibility; both the subsystems and the market packages follow the distribution of costs and ownership typically associated with transportation.

Architecture Assessment

Among the legal issues, tort liability remains a major area of concern in surface transportation. State Departments of Transportation confront millions of dollars in liability claims annually, as do the automobile manufacturers. AAR estimates are that the railroads spend an average of $500 million on liability claims and associated litigation costs. Liability issues associated with the National Architecture can logically be analyzed by focusing in turn on each potentially liable party.

Under current tort law, it is the traveler who bears most of the liability for personal injury and property damage caused by vehicular accidents. The vast majority of automobile accident claims and lawsuits are prosecuted against vehicle owners and operators on negligence theories and are paid by insurance purchased directly by the owners and operators. This owner/operator liability dwarfs the share of the liability currently borne by highway departments and their contractors who are sued for negligence in highway design, maintenance or marking. Nevertheless, highway department liability is increasing dramatically -- much faster than the even smaller fraction of the liability share currently borne by vehicle and component manufacturers through product liability suits.

The implementation strategy envisions an evolutionary deployment of automated highway technology. Here the potential liability problems are less tractable. Most concerns about advanced vehicle system liability arise when these systems dilute the driver’s control of the vehicle. This creates a serious risk that juries will attribute accidents to the vehicle system and its failure as much as to decisions on the part of the driver. Advanced vehicle systems range from intelligent cruise control to headway keeping systems to lane holding controls, to active collision avoidance, to platooning and other more intrusive vehicle controls.

Research on conventional cruise control has suggested that a driver’s control can be diluted, without increasing potential liability for accidents, by designing a control system so that it is easy to disengage and leaves the driver with the psychological impression that he or she continues to be responsible for the operation of the vehicle. It is a considerable leap of faith to apply this approach to AHS which assumes complete control of the vehicle, or even to versions of Intelligent Cruise Control that give complete braking authority to the automated system. People will inevitably purchase these systems for their safety benefits and begin to depend on them for their personal safety. It is difficult to assess the degree to which this liability concern has already slowed the introduction of ICC in the United States; the superficial evidence is that Japanese and European companies have pursued this and advanced lateral control systems somewhat more vigorously than U.S. companies, but it is hard to evaluate the degree to which this may be due to their lesser liability concerns. There are many who believe that public support for an AHS program would have been unnecessary had the liability concern in this country not inhibited private investment.

Deployment Implications

Because the National Architecture does not represent a major shift in liability responsibility, there are not any legal changes required to implement systems that conform with the architecture, particularly in the near term. Nonetheless, steps can be taken to minimize the exposure of participating parties. This includes the development of adequate performance standards for ITS systems, the testing of new systems (through operational field tests, etc.) to obtain data on the performance of new systems relative to the standards, and the ongoing education and training of ITS professionals to ensure that products and services are delivered in a competent manner.

Regarding long-term deployment, the liability risks associated with advanced vehicle systems may be addressed in several ways other than through changes in tort liability laws. These systems will be deployed gradually, starting with the applications that are least intrusive to the driver’s control of the vehicle. Thus, intelligent cruise control, headway control and passive collision avoidance are early deployments that will provide early experience and condition the driver for new, automated vehicle paradigms. It appears likely that operational experience on Intelligent Cruise Control may be forthcoming from Europe or Japan in the relatively near term; this can provide US manufacturers a better basis for assessment of the seriousness of the liability issue here. Fully automated vehicle deployments further in the future will benefit from greater experience with the technology and its liability risks which should make private and public risk management better informed and more feasible.

3.4.6 Antitrust

Antitrust laws in the United States restrict anti-competitive conduct by private entities and in some limited cases by public actors. Of greatest relevance to the National Architecture is the Sherman Act, 15 U.S.C. Section 1 and 2, which restricts monopoly behavior and conspiracies to restrain competition. Violations of the Sherman Act can give rise to severe criminal and civil penalties, as well as to private lawsuits, pursuant to the Clayton Act in which treble damages may be recovered. If present, the threat of antitrust liability would seriously deter the cooperation among private and public entities that is necessary for the architecture to succeed.

Studies of ITS technologies have concluded that the joint ventures and public/private partnerships that are typical of the National Architecture and of much research, development and deployment of ITS can be easily managed to avoid antitrust concerns. Professor Stephen Calkin’s research, ITS and Antitrust: A Preliminary Assessment, emphasizes several features of antitrust law that may apply to the National Architecture. These are, in turn, summarized in Chapter 6 of the DOT Report To Congress on Non-Technical ITS Constraints and Barriers. In general, anti-trust is not viewed as a major barrier to ITS deployment, and the architecture does not alter this overall interpretation. Nonetheless, it is important to recognize salient aspects of the architecture that relate to anti-trust provisions and prudent steps that can be taken to foster a competitive ITS industry.

Architecture Assessment

In devising a nationwide National Architecture for ITS deployment, it is important to ensure a "level playing field" for private sector participation in the provision of goods and services. The open, modular architecture facilitates such participation and, conversely, does not encourage closed proprietary systems. As a result, the risk for unfair market dominance--at least as achieved through architecture decisions-- is minimized. As with any sphere of economic activity, the development of markets and assurance of competition will be the proper domain of the US Department of Justice and related communications and transportation regulatory agencies.

Further, the National Cooperative Research and Production Act of 1993 protects joint ventures which file a notification with the Department of Justice from treble damages for conduct that falls within the scope of the notification. Permissible activities of such immunized joint ventures are fairly restricted. Nevertheless, most joint ventures in which the private sector and TMCs share information about their services, as long as they do not restrict the marketing or distribution on those services, would appear qualify for protection under the Act. With regard to the specific market packages, anti-trust issues would conceivably be most relevant to those areas that had significant private sector involvement. Even in these cases, the potential for anti-trust problems appears minimal. According to the aforementioned FHWA Non-technical Report to Congress, the federal government has passed several major pieces of legislation (such as the aforementioned National Cooperative Research and Production Act of 1993) which aim to minimize anti-trust actions brought against joint ventures. The report concludes that anti-trust is not a manifestly important constraint to ITS deployment. Given the extent to which the National Architecture mirrors existing institutional arrangements, it is not an inherent constraint of the architecture either.

Deployment Implications

Even though anti-trust does not appear to be a central constraint to the National Architecture, it will still be important to ensure that deployment of ITS is done in a competitive manner. The deployment strategy, therefore, features an open systems approach to standards development, which will encourage vendors and suppliers to participate in the program, and guard against unnecessary market dominance in ITS. In a related manner, standard-setting activities in the architecture design require government supervision and involvement so as to avoid the appearance and reality that competitors could conspire, through standards, to impose monopoly power on particular ITS products, services or communications links. Open standards development processes serve to minimize this risk.

Finally, understanding of the scope of the state action exemption from the antitrust laws may be important. States can engage in certain conduct which, if carried out by a private entity, would qualify as a violation of the antitrust laws. This state action immunity, while of decreasing importance in recent years, may nevertheless be an important factor in mollifying antitrust concerns. To the extent TMCs are agents of local governments, they can benefit from state action immunity only to the extent that there is an express delegation of state authority to the TMCs.

In conclusion, Professor Calkin's summary of antitrust issues applies in full to the National Architecture.

> "[State and federal] governments are free to conduct research, develop and build intelligent highways, establish a unifying National Architecture, set standards and engage in host of activities without antitrust risk. Nor would private firms who lobbied the governments, or cooperated with the governments, be liable."

Therefore, the National Architecture poses no significant risk of antitrust actions.

3.4.7 Patents

Because many ITS implementations will involve public and private cooperation, there can be concern (and disputes) about the retention of property rights, the patents, copyrights and other intellectual property rights.. Where there is potential conflict, the allocation of rights is best addressed early on as part of the contractual arrangements between cooperating parties. The governing law here, as well as the concerns of ITS participants, is particularly complex.

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While not unique to ITS, intellectual property rights are a concern since many of the market packages rely on new products and services. Presentations at a recent National ITS Workshop on Intellectual Property Rights revealed that current federal policy encourages private sector participation and retention of property rights, whereas state and local governments can have more limitations and restrictions in the use of public funds. No architecture can entirely avoid the need of its participants to negotiate conflicting desires to control intellectual property rights and licensing thereof.

Deployment Implications
Guidance for the state and local governments can assist in ensuring that concerns about design and product patents do not unnecessarily retard the deployment of ITS services. Experiences with the field operational tests suggest that interagency agreements can be reached and actions can be taken to devise public/private accords on intellectual property rights.

Copyrighting and patenting products produced by teams with public and private funds and interests can be extremely complex. There is, and will continue to be, a need to clarify and remove many ambiguities surrounding proprietary interests of involved parties (e.g., what can/cannot be confidential, who owns what, who should be informed of what, when, by how much, etc.). There is nothing inherent in the architecture which should complicate the process of arriving at mutually acceptable agreements in this area.

3.4.8 Privacy

A number of concerns have been raised about loss of privacy associated with various ITS market packages. This includes concerns over being able to identify vehicles (via network surveillance); the ability to track movements (via dynamic toll and parking management and fleet management); and the potential resale of personal data gathered by traveler information services. The privacy implications of ITS technology have been analyzed in depth pursuant to FHWA contracts and have been addressed by the DOT Report to Congress on Non-technical Barriers. These reports analyze constitutional and statutory privacy rights and find few legal constraints for ITS design. However, privacy concerns are found to create a substantial user acceptance problem. A majority of the public will voluntarily surrender privacy interests -- surveillance and the provision of personal data to public and private service providers -- if they pragmatically believe that the benefits of the technology are significant and outweigh privacy concerns, and if the data is properly protected.

When applied to the National Architecture, three sets of privacy concerns emerge: (1) What <u>restrictions</u> do federal and state constitutional and statutory privacy laws place upon architecture design which permits the surveillance of vehicles and the collection of personal data concerning these vehicles? (2) What <u>requirements</u> do federal and state laws mandate for disclosure of databases (including those arising from state and federal freedom of information acts and records acts?); and (3) Between these extremes (restricted collection of data and required dissemination of data), what architecture design will best facilitate achievement of the social and commercial benefits of ITS while balancing consumer preferences for privacy? The first two issues are legal questions; the third is a public policy question that is ultimately a political choice. The analysis below addresses each question in turn with direct reference to the National Architecture.

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Legal Restrictions on Surveillance and Data Collection and Dissemination

Because vehicles traveling on public highways are in plain view and subject to observation by law enforcement officials and because they are subject to extensive government regulation, the Supreme court and lower courts have repeatedly restricted the scope of the public's reasonable expectation of privacy in vehicles and its right under the Fourth Amendment of the Constitution to challenge motor vehicle surveillance. Thus, the Supreme court has held that automobile owners have no enforceable expectation of privacy in their vehicle identification numbers and that law enforcement officers can enter vehicles without probable cause to view such numbers.

Moreover, vehicle owners who permit electronic monitoring devices to be attached to their vehicles have been held to have consented to subsequent surveillance by law enforcement officials using the devices -- including surveillance of drivers other than the original owners. Although there is no case law in point, the same principle suggests that vehicle owners who voluntarily and knowingly subscribe to an ITS service -- by seeking route guidance, by acting as probes or by equipping their vehicles with monitoring technology -- have consented to the reasonably foreseeable monitoring which follows.

This analysis suggests that the constitutional law of privacy will place few restrictions on ITS implementations with one significant exception. To the extent travelers receive ITS services through private service providers, their "consent' to <u>public</u> surveillance and <u>public</u> access to personal information cannot automatically be implied. An individual can share personal information with another private party without necessarily surrendering a reasonable expectation of privacy to all. Some have argued, in reliance on United State vs. Miller, 425 U.S. 435 (1976), that by sharing data with one organization, the individual assumes the risk that the organization will disseminate that information further. Thus, once a private sector entity is given access to data by a traveler, the traveler has waived any constitutional right to privacy should the provider subsequently share that data with a TMC or government agency.

While this may be true as a matter of constitutional law, it still leaves the individual with a complaint arising from tort law or breach of contract against the private sector. The common law of contract and the tort law of privacy, together with private sector concern with customer satisfaction, will give companies incentives to fully and accurately disclose to travelers how the data they collect will be employed. Thus, different providers, by creating different expectations of privacy in their consumers, may affect the degree to which public agencies can take advantage of data for surveillance and personal information purposes.

A second restriction placed by privacy law on the architecture arises from the Federal Privacy act, 5 U.S.C. Section 552a, and its many State Analogues. If ITS data sets permit the retrieval of data by name or other personal identifiers of individual travelers, the Privacy Act imposes restriction on access to those identifiers to employees on a need-to-know basis and will stand in the way of any dissemination of personal data to private entities in the absence of individual consent. Individuals also have a right of access under the act to data maintained by personal identifiers, with law enforcement files remaining exempt from this requirement in most cases.

Legal Requirements of Disclosure of ITS Data

There are two serious legal regimes that may require access to and disclosure of ITS data and that must be taken into account by ITS implementors. First, a federal standard requires most entities that operate federal computer systems to escrow the keys to encryption of confidential data with federal officials. See Federal Information Processing Standards Publication # 185, Escrowed Encryption Standard (February 4, 1994). This standard will enable law enforcement agencies to conduct lawfully authorized electronic surveillance that has increasingly been frustrated by sophisticated private encryption technologies. Although the Escrowed Encryption Standard has been harshly criticized by private individuals and businesses, it is not mandatory for businesses, universities and other non-profit organizations and citizens who do not operate Federal computer systems and it applies only to voice, facsimile and computer information transmitted in a telephone system.

Second, the Federal Freedom of Information Act, (FOIA) 5 U.S.C. Section 552, together with the Federal Records Act, 5 U.S.C. 701, may require preservation of electronic data sets that contain “records” within the meaning of these statutes as well as case-by-case determination of whether private parties seeking access to the data sets under the acts are entitled to do so. A “record” under the Federal Records Act is a document: “made or received by an agency of the United States government under federal law or in connection with the transaction of public business” and “preserved or appropriate for preservation by that agency... as evidence of the organization, functions, policies, decisions, procedures, operations or other activities of the Government or because of the information value of data in it."

This definition has been held to encompass electronically generated communications, including electronic mail. Similarly, the Freedom of Information Act defines "record" as including a wide array of broadly defined "writings" which include electronically conveyed or stored data. Most states have analogous records acts and freedom of information acts and look to federal construction of the federal statutes for guidance in interpreting their own acts. Thus, to the extent ITS databases are held in the hands of state or federal governmental entities, they are likely to be subject to recordkeeping and disclosure statutes.

One study of the Federal Freedom of Information Act minimized this concern by noting that the Federal Act contains an exemption for information which, if disclosed, would be likely to result in a clearly unwarranted invasion of privacy. Unfortunately, this exemption -- number 6 to the federal and many state FOIAs -- does not provide an easy solution to privacy concerns. The exemption must be administered on a case-by-case basis requiring the public agency to demonstrate, in response to a particular request, that the balance should be struck in favor of non-disclosure. Agencies have in the past found this type of FOIA claims processing to be time-consuming and expensive. ITS can accentuate this issue since it collects and potentially archives vast amounts of information in the course of ITS service provision.

Balancing Privacy Concerns in the Wide Area Between Legal Restrictions on Disclosure and Legal Requirements of Disclosure

Finally, and most importantly, the architecture implicates policy choices that are not legally mandated between protecting privacy and maximizing the utility of ITS data. The National Architecture is careful to be flexible in these choices on several levels.

First, the National Architecture permits considerable variance among public and private sector providers in terms of how access will be limited to ITS data. The flexibility permits different choices when regional attitudes on privacy issues vary. For example, in some areas concern for safety and personal security may lead to greater public acceptance of data maintenance on particular vehicles; whereas in others, concerns for freedom from surveillance may be paramount. The National Architecture does not make these policy choices.

The National Architecture further facilitates individual choices with respect to privacy by permitting multiple, private sector providers to offer competing products, each of which may have a different degree of privacy in the design. The range of privacy choices, offered because multiple providers can use regional information assures that fewer consumers will opt out of the National Architecture entirely out of privacy concerns. The architecture permits different travelers to make different privacy choices, thus facilitating ITS deployment.

Deployment Implications

A range of actions will need to be taken to preserve privacy. This can include the development of guidance and agreements for protecting identities of individuals and building in technical safeguards to relevant subsystems. Like many other institutional challenges, the requirement to maintain privacy is not unique to ITS. Other industries have successfully implemented distributed systems with significant privacy and security requirements. ITS implementations should rely on these existing and emerging mechanisms when possible. For example, both the banking and communications (e.g. cellular) industry have billing systems which could be applied to a variety of market packages, including passenger and fare management and dynamic toll/parking management.

Regarding surveillance, there are fewer parallels and extant practices to aid ITS implementation. The key issue is the individuals expectation for privacy, and related public objections to "big brother" practices. While the courts have generally ruled that actions on the highway should not be considered "private" (see FHWA, 1994), it is nonetheless important that ITS implementation minimize intrusion through surveillance. Thus, supporting guidelines should be developed to assist in deploying surveillance-oriented packages. The packages would include network surveillance, probe surveillance, dynamic toll/parking management, and fleet management.

3.4.9 Education and Staffing

The education and staffing requirements to deliver ITS products and services will represent a significant challenge to the transportation and communications industry. While reports by the Urban Institute suggest that this demand will eventually be met through the market place, there is nonetheless the challenge of taking the necessary training and education steps to ensure the early successful implementation of ITS. Such training would encompass the architecture as well as the technical and non-technical issues associated with conforming ITS implementations.

From another perspective, ITS represents a source for new, highly skilled jobs. Many of the required skills are available through other industries such as Computer Integrated Manufacturing and Defense. Transportation is a fruitful area to apply these skills and has the advantage that it can be moved into quite easily due to the pervasive role of transportation in our society. Everyone brings extensive, previous experience as a user to the transportation industry.

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ITS technologies and systems will place new educational and training requirements on transportation professionals. In addition to current skills in transportation engineering, ITS will require enhanced knowledge of both information and transportation systems. In addition, ITS places new requirements for skills in procurement, management, and administration. Forums conducted as part of the National Architecture program have revealed training needs for ensuring applicability of the architecture to regional and local ITS systems. This will be an especially critical early need as major ITS designs progress ahead of the supporting standards development efforts.

Over time, the need for highly customized training could level off, as various deployment options and systems become increasingly routine and/or standardized. Indeed, one of the key advantages of the National Architecture is that, over time, the standard interfaces will become more common-place, thereby reducing the need to specialized training. However, this will not reduce the aforementioned general requirement for systems and informational technology skills for the new generation of transportation professionals.

Deployment Implications

While the issue of education and training transcends the architecture, there are important connections. In order for an architecture to be successful, it must be applied, and in order for it to be applied, it must be understood. Developing training courses on utilizing the National Architecture would help fulfill this goal. For example, an early training need would address the development of regional architecture approaches and public/private approaches to deploying architectural elements. Training requirements for systems integration will increase as deployment of the architecture increases. In keeping with other elements of the National Architecture, the use of existing educational infrastructure would be encouraged as a mechanism to provide such training.

For public sector deployment, one key area is in the staffing and managing of regional transportation management centers (TMCs). Locales with operational TMCs will already have operators and technicians with the necessary skills and, as components of the architecture are deployed, these personnel can be retrained as needed. Many regions, however, have little or no transportation technology and this will create staffing problems. In rural parts of the country there may not even be a traffic signal; while in certain metropolitan areas there are sophisticated traffic management centers that use a multitude of electronic devices and systems to monitor traffic flow, automatically control traffic signals and manage incidents. Therefore, the number of agency staff members having the necessary education and skills required to maintain the new equipment ranges from zero to many.

In regions where no technology is in use today, the creation of TMCs will require more than just hiring or training of operators and technicians. Management organizations will have to be created and managers and supervisors with specialized education and training will have to be hired. The regional nature of the ITS TMCs will ease this task if one or more member agencies is experienced in the operation and management of ITS systems. Every effort should be made to organize the TMCs so that this is the case. In areas where TMCs exist, the necessary organization is in place and there is a pool of trained personnel available. Also, there are many agencies that do not have traditional TMCs, but they have technically trained people that perform various functions, including making traffic counts, maintaining the counting equipment, servicing toll equipment and communications systems. This existing staff will form the backbone of the ITS operations and maintenance staff. Training will be required as new subsystems are deployed, but this staff will already have the basic knowledge and experience required.

Private sector staff will be responsible for the operation and maintenance of many ITS services. There are three sources of maintenance services that must be considered. These are agency staff, the equipment manufacturer’s field service staff and private service providers. Each approach has its place and all three will most likely be used during the various stages of deployment. The type of service provider used will be a function of the: availability of trained technicians, deployment phase, geographic setting, and the extent of existing ITS infrastructure.

Availability of technical professionals is critical. No matter who will be the primary maintenance service provider, the transportation agency must have in-house staff capable of understanding the operations and functions of the TMC and the roadside infrastructure. These professionals must be capable of interpreting the outputs from the system and communicating with the service provider.

In certain deployment scenarios and stages, the use of in-house staff will be the most efficient means of providing service. The most obvious example is where TMCs are in operation and a trained staff exists. In other scenarios and stages, the private sector can be expected to take a significant role in managing the system, and in a related sense, providing the technical support for public sector activities. For example, in some metropolitan areas, the private sector is expected to take a leading role as “information service providers”. Consequently, these companies will be faced with the burden of training its employees in the various aspects of National Architecture and design.

Crosscutting these education and training requirements are the educational institutions. There will be increasing pressure to change not only the content of formal educational curriculums, but to change of delivery format as well. Regarding the former, both undergraduate and graduate programs will need to consider how informational technology and system design courses can be integrated into transportation engineering and planning programs. As for the latter, the emergence of the “information age” also presents new opportunities to develop distanced-based courses that can facilitate continuing education of transportation professionals, without the physical requirement to be at the university. Given the inherently diffuse nature of ITS systems--and the limited availability of training funds--such approaches could facilitate the timely dissemination of National Architecture information.

3.4.10 Regulatory Constraints

As recognized by the institutional layer of the National Architecture, ITS deployment involves a host of investment and procurement decisions. While some of these decisions will fall within the normal purview of the public and private sector, many of the market packages will represent significant challenges to both sectors. State and federal regulations governing motor vehicle safety, motor vehicle licensing and registration, environmental quality and land use may all be implicated in particular ITS applications.

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On the public sector side, high-technology procurements are generally viewed as difficult for the public sector for they are not amenable to low-bid procurements, etc. Also, establishment of public/private partnerships in the deployment of market-packages can evoke concerns about various practices, such as retention of intellectual property constraints. While the National Architecture does not inherently mandate such new arrangements, they are inherent to ITS and therefore need to be addressed as part of the deployment.

Deployment Implications

The deployment of ITS needs to recognize that procurement and related regulations--while not major impediments--can delay the achievement of needed early benefits and increase the costs for all sectors. Consequently, a diversity of approaches for encouraging ITS deployment will need to be followed. This includes guidance on procurement streamlining and public/private partnerships, standards development to promote open product development, and strategic financial incentives to promote efficient and innovative investment action. In terms of market packages, the issue of procurement streamlining is expected to influence public sector related services--such as ATMS and APTS--while frequency requirements will most directly affect packages utilizing short range communications and advanced vehicle applications.

3.4.11 Budget Instability

As described in section 3.1, the focus of ITS deployment decisions are at the local level. Several major ITS studies (including DOT, 1995, Booze, Allen and Hamilton, 1995, and Horan, et al) have found that budgetary constraints remain an important concern for local implementors implementing possible ITS solutions. The architecture is aimed at minimizing the marginal cost of conformance through its open and distributed nature. Nonetheless, deployment considerations should be sensitive to scaling deployments relative to expected ITS benefits.

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With the local implementation budgetary constraints as background, the possible budgetary impacts of an “architecture compatible” ITS system is an understandable concern among local implementors. For example, should compatibility with an architecture standard require elaborate systems, many jurisdictions would be faced with sacrificing needed transportation improvements for necessary ITS system designs with uncertain benefits.

Fortunately, the National Architecture does not impose any immediate standards on ITS design; rather it highlights areas where standards would be beneficial and appropriates the standard decision-making process to organizations typically involved in transportation standard setting.

The budgetary impacts of implementing ITS systems should be determined through the regional transportation planning and programming process. This forum would also provide the appropriate opportunity for analyzing the cost-benefit tradeoff of ITS core functionalities vis a vis other transportation improvements.

Deployment Implications

While the National Architecture does not “require” immediate standards, it would be an under-representation to suggest the architecture is devoid of possible budgetary implications. Certainly the range of functionality conveyed by the physical architecture has the potential to require considerable public and private sector resources.

In the case of major corridor and regional ITS systems, the cost of utilizing the physical architecture is minimized to the extent to which these systems can pro-actively incorporated into ongoing capital improvements (e.g. buying "smart"). At the regional planning level, the aforementioned alternatives analysis can provide an objective basis for investing in ITS systems vis a vis other improvements.

Notwithstanding these fiduciary approaches to assessing architecture value, there is a recognition of the budgetary reluctance for early architecture compatibility. For this reason, the Intelligent Transportation Infrastructure Initiative can appropriately be viewed as a mechanism for encouraging leading innovators of open and compatible systems, thereby lower the potential costs to subsequent adopters.

3.5 Summary: Implications for the Implementation Strategy

The greatest challenge of the implementation strategy is to establish guidelines for intelligent implementation of the architecture allowing skillful navigation through the numerous, complex socio-economic deployment challenges. As outlined in this chapter, the strategy has to mitigate some unique conditions of ITS development and deployment, which include, but are not limited to, the following:

- Unprecedented high expectations of ITS, which go beyond simple improvements to the transportation system to include socio-economic and environmental impact areas as well.
- High cost of producing, deploying, and maintaining the hardware and software systems.
- Uncertain benefits that can be realized only under long-term investment plans.
- Budgetary constraints of participating organizations.
- Unwillingness and/or the inability of the public sector to move the entire ITS program on its own.
- Potentially difficult organizational changes that might be required to introduce ITS.
- Complicated metropolitan-institutional arrangements required for regional management of ITS.
- Complex interoperability requirements among regions and across state lines.
- Unparalleled diversity of the market place, geography of regions, and the demographics of user communities.
- A multitude of training and education requirements.

The institutional layer accents the non-technical features which may facilitate and/or inhibit ITS implementation. While the particular institutional constraint (or opportunity) will undoubtedly vary across the different implementors, there a number of crosscutting issues that merit inclusion in the implementation strategy. One major venue for discussing such implementation is at the state and local level. In addition, there are a variety of implementation actions that can be taken at the federal level; These two implementation venues -- state/local and federal -- are treated in the subsequent sections.

4. State and Local Guidance

State and local transportation agencies play a pivotal role in identifying the transportation problems facing a community and formulating appropriate and cost-effective solutions for these problems. These agencies will determine which ITS services are deployed and will be involved in selecting between many potential implementation options for each deployment. In most cases, ITS will not replace the existing transportation systems and services, but rather will allow them to perform more efficiently. For example, ITS will not replace tow trucks for clearing incidents, but it will locate and dispatch the trucks more effectively.

Figure 4-1 shows the transportation system implementation process at the very highest level. As indicated in the figure, the architecture products are most applicable to the planning phase since this is when regional strategies, and regional architectures, are formulated. Standing to gain the most from the Architecture are implementors working towards integrated transportation management solutions and the private providers that will supply the products and services needed to support these regional approaches. The Architecture focuses on the inter-agency interfaces that enable such solutions. There is lesser emphasis on guidance for implementation of specific projects once the general integrating framework has been defined; such detailed guidance is better left to specialists familiar with the specific local requirements.

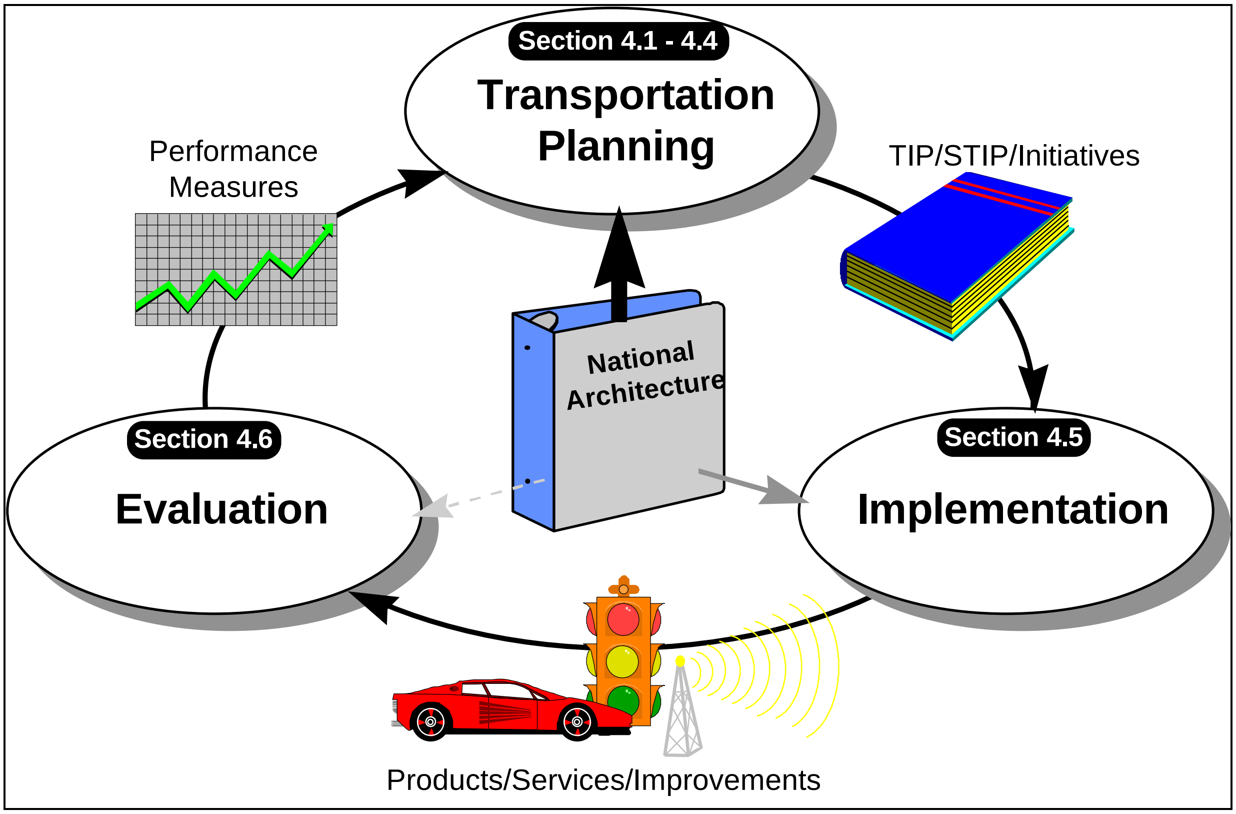


Figure 4-1: ITS Implementation

The National Architecture is a general framework that was developed to facilitate cost-effective introduction and integration of a wide variety of ITS services. This section provides guidance to the transportation professional on available implementation options and the implications of the Architecture on these implementations. The information is intended to assist in selection from the various options to achieve tailored implementations best suited to regional needs. Information on potential ITS benefits, design options, and standards implications are excerpted from the Architecture deliverables and presented in this section to support this objective.

After summarizing the ITS Planning Process in Section 4.1, sections 4.2 through 4.4 elaborate on the implications of the National Architecture at several steps in the planning process. Section 4.5 discusses the Architecture's implications on the implementation of planned ITS projects. Section 4.6 covers the architecture's potential impacts on the evaluation of operational ITS projects.

4.1 Applying the Architecture in Surface Transportation Planning

ISTEA and related legislation have strongly reinforced the role of state and regional transportation planning in guiding transportation decisions, including ITS deployment. Except for in-vehicle safety and guidance systems, other consumer electronics, and services related to management of commercial vehicles, implementation of ITS will be local or regional and will take place within the context of the overall regional transportation planning process discussed in section 3. Over the course of this and subsequent sections, the activities summarized in table 4.1-1 are recommended to include the Architecture into this process. State, Regional, and Local activities are highlighted in the lower portion of the table.

Table 4.1-1: Identified Regional Planning Support Activities

	Suggested Activities
National	• Continue/Expand Outreach Targeting Regional Champions • Revise ITS Planning Guidance • Education and Training on Architecture Implications for Planning • Education and Training on Developing and Supporting a Regional Architecture • Develop and Communicate Cost/Benefits Information Suitable to Support Regional Planning decisions • R&D to Enhance Ability to Model ITS Benefits and Environmental Affects
State/ Regional	• Evaluate Potential ITS Solutions For Application in Region • Map ITS Solutions to National Architecture Standards Requirements • Develop Regional Architecture with Emphasis on Major Inter-Agency Interfaces • Extend Outreach to Local Elected Officials/Other Decision Makers • Make Provision in Future RTIP Updates For Desired ITS Projects • Maintain Regional Architecture through Controlled Changes
Local	• Participate in Regional Architecture Development • Assess Regional Architecture Impacts on Current/Planned Projects

At the national level, the process of mainstreaming ITS into the conventional transportation planning process can be encouraged through activities that develop and endorse ITS Planning Guidance, extend education and training on the architecture and its implications, and provide cost-benefit information for ITS implementations. These activities are further described as part of the DOT recommendations in section 5.

At the state or regional level, agencies should evaluate the applicability of ITS for local or regional needs, develop an integrated transportation management plan, extend outreach to local and other decision makers, and eventually make provision in future Regional Transportation Improvement Plan updates for selected ITS projects.

4.1.1 ITS Planning Process Overview

The *Interim Handbook on ITS Planning* (FHWA, 1996) defines the planning process depicted in figure 4.1-1. This process refines and augments the earlier *IVHS Planning and Project Deployment Process* (FHWA, 1993) guidance document, taking into account the National ITS Architecture along with many other enhancements aimed at better integrating the ITS planning process with Surface Transportation planning. The ITS Planning Process explicitly recognizes that ITS is not the only means of mitigating transportation problems, nor is it cost-effective for all regions and for all problems. Starting with this open premise, the process develops a framework that integrates new ITS technologies with existing conventional systems. It is anticipated that as implementation experience with ITS increases, the ITS Planning Process will become increasingly integrated in the overall transportation planning process. Table 4.1-2 provides a brief overview for each of the identified steps in the planning process. Refer to the FHWA handbook for additional information.

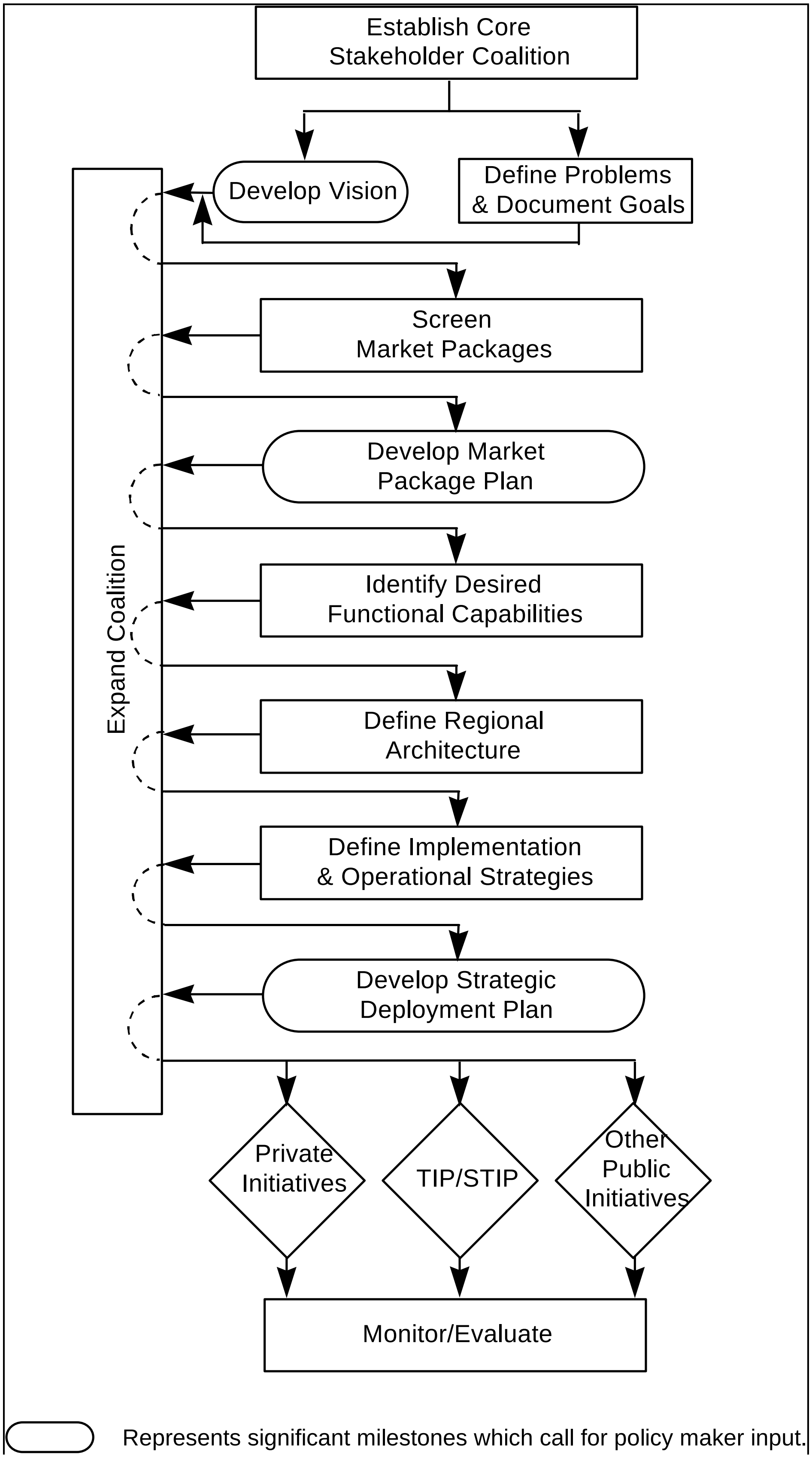


Figure 4.1-1: ITS Planning Process

Table 4.1-2: ITS Planning Process Steps

ITS Planning Step	Description
Establish Core Stakeholder Coalition **Expand Coalition**	Coalition of involved organizations remains a key requirement after architecture adoption. It should be viewed and fostered as a continual process. The national architecture provides a technical framework that assists with regional integration of systems. Precisely if, when, and how this integration will occur within a particular region can only be determined by engaging each of the involved parties.
Define Problems & Document Goals	Products are System Needs Definition and Existing System Inventory. In view of the problems, the goals of the eventual system should also be developed.
Develop Vision	This step defines the long-term vision for the future regional transportation system. The Vision is developed as a short, approachable product that can be used to focus the attention of the initial coalition. It provides a platform for establishing ITS goals and objectives and serves as an important benchmark for the remainder of the project. All other activities in the planning process should be predicated on the fact that they help to achieve the vision. Moreover, a well-crafted vision serves as a significant aid in attracting additional members of the coalition. By demonstrating how ITS is envisioned to work within the regional transportation system, stakeholders will clearly be able to see how their activities may be affected by ITS.
Screen Market Packages	This step considers the spectrum of transportation improvements available to the regional planner, including alternatives to the identified user services. The range of available solutions are evaluated to determine those services most appropriate for implementation in the region. Where the architecture explicitly supports an alternative, the applicable Market Package is identified. In the refined process, the implementor is selecting from the Market Packages rather than User Services, since Market Packages distinguish between User Service components that are implementable over short-, medium, and long-terms. The Market Packages also have a direct linkage to the underlying architecture that is helpful in subsequent steps. This step would benefit from an “Implementor’s Handbook” that provides an expanded treatment of the implementation options and associated costs, benefits, and risks.
Develop Market Package Plan	Documents the Market Packages that should be implemented over time. Sequencing based on local priorities, deployment dependency guidance, and tailoring of national deployment strategy guidelines. These plans can be integrated with the mainstream planning documents (e.g., the Regional Transportation Plan) as issues are resolved and potential funding sources are found.
Identify Desired Functional Capabilities	Desired functional capabilities should be explicitly defined based on local characteristics. Better insight into appropriate functional capabilities will also be gained through subsequent evaluation of the implemented project and on-going evaluation of similar projects in other areas. The desired functional capabilities should be defined based on a set of performance criteria. The ground-up systems engineering analysis normally associated with this step is a sound but time and resource-consuming approach oriented towards development of custom solutions to one-of-a-kind problems. Use of the architecture products and subsequent standards can streamline this process since it should enable standardized building blocks for many of the basic ITS components. Definition of standard, higher-level components will ease the job of system specification by effectively reducing the level of granularity to which the systems analyst must go.
Define Regional Architecture	The high level architecture is refined. Communications choices, technology choices, and allocation of information management and control processing capabilities within the regional transportation system are developed to define a regional architecture. The process of regional architecture definition involves three steps: 1. Map Existing Systems to National Architecture Framework: The existing system inventory and local institutional framework are mapped to the physical architecture framework. 2. Assess Existing System National Compatibility: Standards Requirements are identified for each interface and compatibility with these requirements, and any identified standards is determined. 3. Determine Costs/Benefits of Achieving Compatibility: Normally systems will evolve towards compatibility as equipment is upgraded or replaced. The cost of retrofitting existing systems to be architecture compatible, whether in the context of a system upgrade or a stand-alone project, is determined and weighed against estimated costs of incompatibility. Where cost-effective, compatibility attainment is planned.
Define Implementation & Operational Strategies	The analysis expands the previous step by adding consideration for operational strategies, including human resources, education and training needs, etc.
Develop Strategic Deployment Plan	At this step, the general strategies, defined regional architecture, and identified market packages are refined and translated into a sequenced set of specific projects.
Private Initiatives **TIP/STIP** **Other Public Initiatives**	This step reflects the programming and implementation of the identified projects. It divides projects by funding initiatives, including present funding sources, and new ones from private and public initiatives.

ITS Planning Step	Description
Monitor/Evaluate	The implemented projects are monitored and evaluated to determine their true costs, operational benefits, and other measures of system performance. Project evaluation results enhance future planning in the region and provide vital input to data collection efforts at the regional, state, and national levels.

4.1.2 Applying the Architecture Products

The National Architecture definition and supporting analysis is documented in many extensive volumes. Many of these documents can be referenced and used in the ITS planning process and in development of the selected ITS products and services. Figure 4.1-2 illustrates the potential uses for several of these documents. The documents with the greatest potential for application in the planning process are shown near the top of the page. The elements of the existing transportation planning environment are shown on the left. The three boxes in the middle focus on major steps in the ITS planning process and their associated tasks. In practice, the planning process will often be incremental and iterative though it is shown in simple step-wise fashion in the figure. Other national ITS programs that may influence the planning process are shown at the bottom of the page. The potential use for each of the Architecture documents in this process is addressed in the following text and then further elaborated in the remainder of section 4.

Several of the architecture deliverables contain information that can be used to characterize and evaluate the potential ITS solutions that are prioritized in a Market Package Plan. This information supports evaluation of ITS solutions and other potential transportation improvements in a manner that is sensitive to local needs and begins with already in-place systems.

The *Vision Document* is an approachable narrative description of the operation of various ITS products and services from the perspective of the operator and end user. This document provides a useful input for development of a more specific vision statement that begins the ITS Planning Process. Broad distribution of the regional vision can aid in critical outreach and consensus building efforts. The regional vision will undergo revision and refinement as the original, broad vision is translated and refined into more specific plans and projects.

Though the definition of problems and goals will vary markedly by region,*the Mission Definition* can provide general supporting material for this definition. The Mission Definition defines national goals and objectives for ITS and provides preliminary analysis that applies these goals and objectives to representative regional scenarios. It builds on these objectives to form general principles and high-level operational requirements for ITS.

This *Implementation Strategy* provides the most direct treatment and guidance for each of the major planning steps identified in the figure. The market packages which provide an initial menu of ITS options are defined here (reference section 2.2 and Appendix A). Section 4.2 focuses on development of a Market Package Plan which provides guidance for selecting from these options.

Portions of the *Evaluation Results* (the *Performance and Benefits Study* and *Cost Analysis* documents) provide preliminary benefits and cost information that can be used as an aid in initial evaluation of the candidate market packages. More detailed assessments can then be developed for the more promising options. Information from the Intelligent Transportation Infrastructure initiative is also a primary consideration in identifying and prioritizing regional deployments.

Once a Market Package Plan is developed, the *Implementation Strategy, Logical Architecture, Physical Architecture*, and *Communications Document* can be applied as a regional architecture is developed. A regional architecture will facilitate interoperability and inter-agency integration of transportation management. This *Implementation Strategy* defines a process for applying the architecture definition to the existing and planned transportation systems in the region. Through this process, the physical subsystems and special constraints identified by the *Physical Architecture* are applied to the local system(s).

Following the traceability between Physical and Logical Architectures, the detailed functional requirements and data flows defined in the *Logical Architecture* may be applied to the local system. Selective application of these detailed requirements can assist in developing functional specifications at varied levels of detail to support ITS product or service planning, procurement, and design. Detailed communications service specification and telecommunications trade studies documented in the *Communications Document* can provide a head start in specifying the communications elements of the regional architecture. Standards, which will be defined by national or international standards development organizations, will also influence this regional architecture definition process.

The *Implementation Strategy* provides guidance in translating the state or region’s Market Package Plan into a sequenced set of specific projects identified in the Strategic Deployment Plan. Reports on the FHWA field operational tests (FOTs) and Model Deployments may also be useful at this stage. The detailed interface specifications provided in the *Logical and Physical Architecture,* the *Standards Requirements* derived from these interface specifications, and the actual standards, once available, can be used during the actual design and implementation of the selected projects.

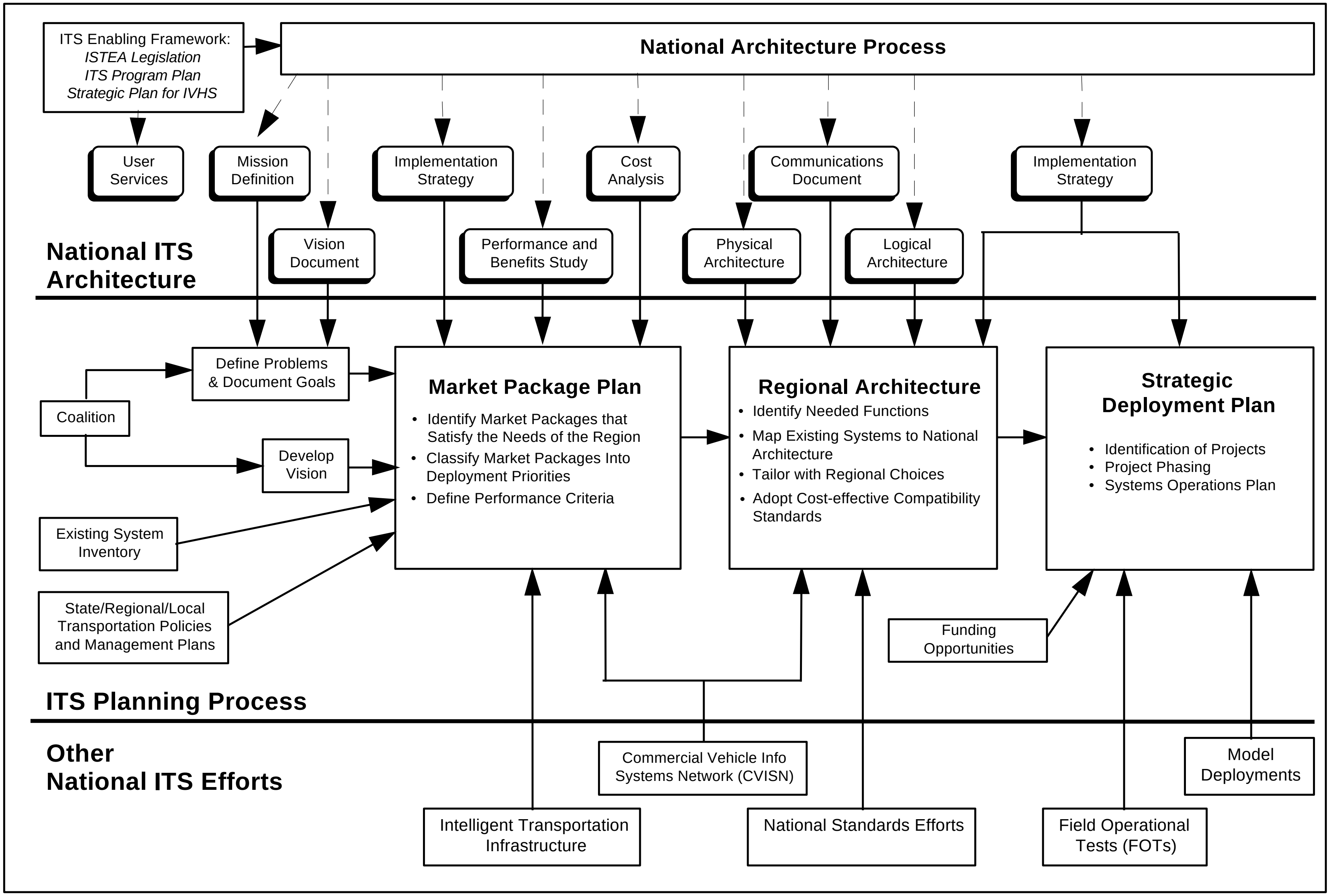


Figure 4.1-2: National Architecture Products and ITS Planning

4.2 Developing a Market Package Plan

The identification of problems, inventory of regional transportation system assets, and cultivation of institutional coalition that begin the ITS Planning Process were familiar to the regional planner before ITS and are largely unaffected by the National Architecture. In the next planning step, the most effective and cost-efficient solutions to the region's problems are identified. A broad range of alternative solutions may be applied to solve the identified transportation problems, only some of which are labeled as "ITS" and directly supported by the National Architecture. Other viable solutions include both conventional transportation improvements and alternative advanced technology applications not specifically covered by the architecture.

Table 4.2-1 provides a range of solutions that can be considered to address the problems identified earlier in the ITS planning process. Note that the distinction between "conventional" and "advanced" transportation solutions identified in the table is often obscured since there are many examples where "conventional" solutions are implemented in innovative ways and other examples where "advanced" solutions have been implemented using manual systems for years.

The column in the table which identifies "Supporting Market Packages" provides the necessary linkage between the general solutions and the national architecture to support succeeding steps in the process. As implied by the table, the conventional transportation solutions do not map directly into the National Architecture. In addition, there are several advanced solutions (such as telecommuting) which are not directly supported by the national architecture definition. Complete descriptions for each of the Market Packages defined by the architecture is included in Appendix A.

This evaluation of the broadest range of alternative solutions begins to mainstream ITS into the transportation planning process. It also highlights issues that must be resolved before ITS solutions can compete on an even footing with other alternatives. For instance, a reliable forecast of the benefit of the potential ITS solutions must be available to allow ITS solutions to be weighed against other approaches. A clear understanding of the relationship between the potential ITS project and the environment is also necessary, especially in areas that have not attained the air quality standard. Since most projects are analyzed against the fifteen planning factors identified in ISTEA, benefits information must be developed so that ITS projects can be measured in this context as well.

Information on benefits that has been developed in the course of architecture development is summarized in section 4.2.2. This section, and the more detailed treatment included in the *Performance and Benefits Study,* provides a qualitative assessment of the benefits for each of the defined market packages. This general information can be augmented by several reports which consolidate the quantitative ITS benefits information that is available. As new results from the Field Operational Tests and other early deployments become available, these initial estimates can be updated, their ranges narrowed, and their degree of objectivity increased.

Developing a market package plan involves input from both the architecture program and elsewhere, as illustrated in Figure 4.1-2. Material in Section 2 of this document covers a range of technical issues necessary for this development. Synergies identified by the Architecture and technology and standards requirements for each market package are shown in Sections 2.4 through 2.6. Section 2.7 identifies a set of early market packages for early deployment consideration. Section 2.8 further focuses attention on the subset of early market packages that are included in the Intelligent Transportation Infrastructure.

Regardless of the market packages that are selected, consensusamong institutions must be reached on the selected solutions, priorities, and timing. Fortunately, ISTEA and the Clean Air Act were designed with specific provisions to create climates for such cooperative inter-jurisdictional relationships and integrated solutions.

Once a Market Package Plan or equivalent ITS-specific plan has been developed and potential funding sources identified, the initial ITS improvements (5-7 year horizon) should be included in the Regional Transportation Plan (RTP) in the context of a normally scheduled update.

Table 4.2-1: Connecting Problems, Solutions, and the National Architecture

Problem	Solution	Conventional Approach	Advanced Systems Approach	Supporting Market Packages	Considerations
Traffic Congestion	Increase roadway capacity (vehicular throughput)	• New roads • New lanes	• Advanced traffic control • Incident Management • Electronic Toll Collection • Corridor Management • Advanced vehicle systems (Reduce headway)	• Surface Street Control • Freeway Control • Incident Management System • Dynamic toll/parking fee management • Regional Traffic Control • Railroad Operations Coordination • Advanced vehicle longitudinal control • Automated highway system	Conventional • Environmental constraints • Land use and community resistance • High cost of construction Advanced • Near-term services yield modest benefits • Latent demand effects • Inter-jurisdictional issues
	Increase passenger throughput	• HOV Lanes • Car Pooling • Fixed route transit	• Real-time ride matching • Integrate Transit and Feeder Services • Flexible route transit • New personalized public transit	• Dynamic Ridesharing • Multi-modal coordination • Demand Response Transit Operations	• Privacy and personal security
	Reduce demand	• Flex Time Programs	• Telecommuting • Other telesubstitutions • Transportation Pricing	• Dynamic toll/parking fee management	• Significant component of demand relatively inelastic.
Lack of Mobility and Accessibility	Provide User Friendly Access to Quality Transportation Services	• Expand Fixed Route Transit and Paratransit Services • Radio and TV Traffic Reports	• Multi-modal pre-trip and en-route traveler information services • Respond Dynamically to Changing Demand • Personalized Public Transportation Services • Common, enhanced fare card	• Interactive Traveler Information • Demand Response Transit Operations • Transit Passenger and Fare Management	Conventional • Declining ridership Advanced • Interjurisdictional cooperation • Standards • Equitable access to information
Disconnected Transportation Modes	Improve Intermodality	• Inter-agency agreements	• Regional Transportation Management Systems • Regional Transportation Information Clearinghouse • Disseminate multi-mode information pre-trip and en-route	• Regional Traffic Control • Multi-modal Coordination • Interactive Traveler Information	Conventional • Often static and/or slow to adapt as needs change. Advanced • Existing system incompatibilities • Standards

Problem	Solution	Conventional Approach	Advanced Systems Approach	Supporting Market Packages	Considerations
Severe budgetary constraints	Use existing funding efficiently	• Existing funding authorizations and selection processes	• Privatize Market Packages • Public-private partnerships • Barter right-of-way • Advanced Maintenance Strategies	• Transit maintenance	• Market uncertainties make private sector cautious • Telecommunicatoins deregulation makes right-of-way barter a near-term opportunity.
	Leverage new funding sources		• Increased emphasis on fee-for-use services	•	• Equity
Transportation following emergencies	Improve disaster response plans	• Review and improve existing emergency plans	• Establish emergency response center (ERC) • Internetwork ERC with law enforcement, emergency units, traffic management, transit, ...	• Emergency response • Incident Management System • Emergency Routing	Conventional • Interagency coordination challenges Advanced • Interagency coordination challenges • Standards
Traffic accidents, injuries, and fatalities	Improve safety	• Improve roadway geometry (increase radius of curvature, widen lanes,...) • Improve sight distances • Traffic signals, protected left hand turns at intersections • Grade Separate Crossings • Driver training • Sobriety check points • Lighten dark roads to improve visibility/better lighting • Reduce speed limits/post warnings in problem areas	• Partially and fully automated vehicle control systems • Intersection collision avoidance • Automated warning systems • Vehicle condition monitoring • Driver condition monitoring • Driver vision enhancement • Advanced Grade Crossing Systems • Automated detection of adverse weather and road conditions, vehicle warning, and road crew notification • Automated emergency notification	• All AVSS Market Packages • Intersection collision avoidance • In vehicle signing • Vehicle safety monitoring • Driver safety monitoring • Driver visibility improvement • Standard Railroad Grade Crossing • Advanced Railroad Grade Crossing • Network surveillance • Traffic information dissemination • In vehicle signing • Mayday Support	Conventional • High costs • Human error is primary cause Advanced • Mixed results for initial collision warning devices • Relatively slow roll out for AVSS services anticipated • Tort liability issues hinder innovative deployments • High speed grade crossing systems may require extended closure times

Problem	Solution	Conventional Approach	Advanced Systems Approach	Supporting Market Packages	Considerations
Air Pollution	Increase transportation system efficiency, reduce travel and fuel consumption	• More efficient conventional vehicles • Vehicle emissions inspections • Promotion of alternatives to single occupant vehicle travel • Increased capacity to reduce vehicle delay • Regulations	• Remote sensing of emissions • Advanced traffic management to smooth flows • Multi-modal pre-trip info • Telecommuting • Other telesubstitutions • Transportation Pricing • Alternative fuel vehicles	• Emissions and environmental hazards sensing • Surface Street Control • Freeway Control • Regional Traffic Control • Interactive Traveler Information • Dynamic Toll/Parking Fee Management	Conventional • Increasing demand can offset initial benefit of added capacity. • Regulations, inspections are unpopular and onerous. Advanced • Increasing demand can offset efficiency improvements.

4.2.1 Starting with User Service Based Plans

The previous discussion assumes that the prospective implementor is taking a fresh look at potential ITS implementations and, following the current ITS Planning Process, will progress directly from problem definition to an identification of the market packages that are best suited to the implementing region. The selected market packages can then be documented in the Market Package Plan.

For at least 75 of the largest metropolitan regions across the country, much of this work has already been performed in the course of Early Deployment Plan (EDP) development. Figure 4.2-1 shows the ITS planning process that has generally been used, with some tailoring and augmentation, in preparing these EDPs. This process is documented in the *IVHS Planning and Project Deployment Process* dated April 1, 1993. The most substantial difference between the first few steps of this process and the initial steps of the process defined in section 4.1 is that the user services are used as the palette of implementation alternatives in the process below.

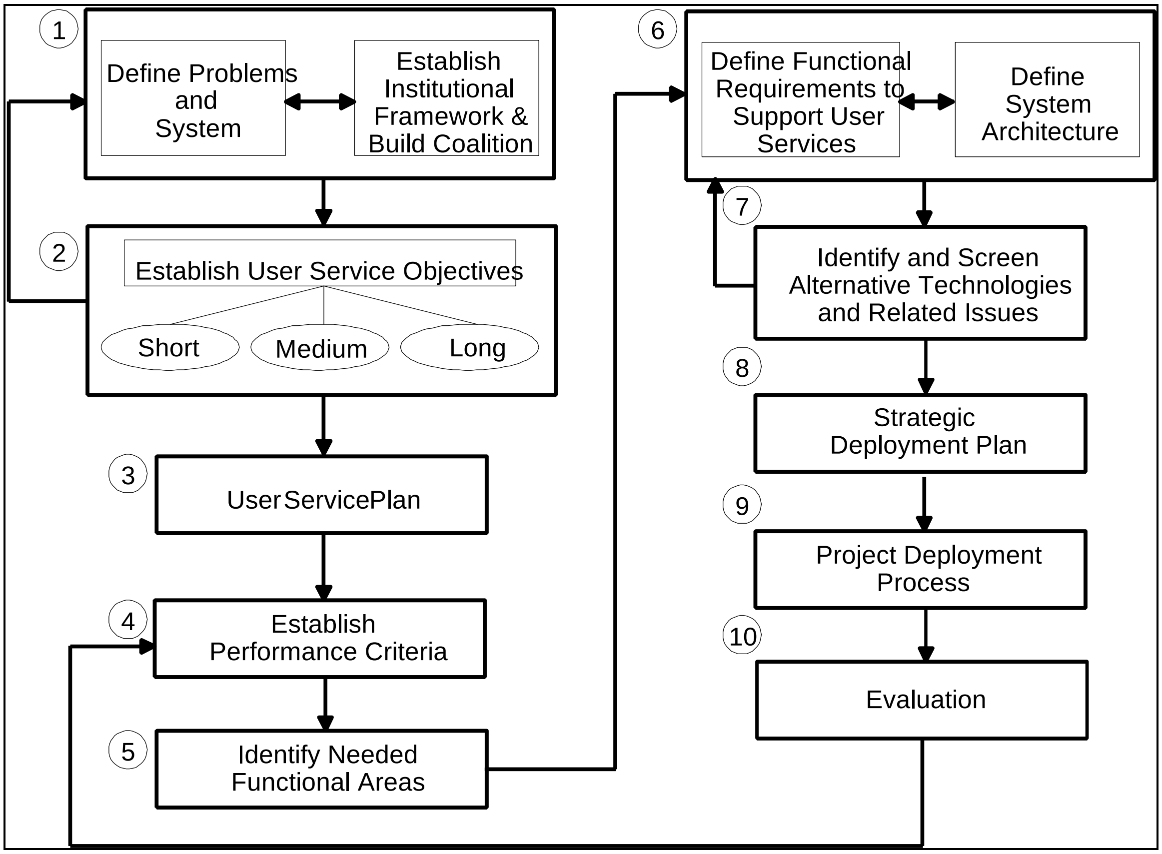


Figure 4.2-1: Guiding Process For Many Early Deployment Plans

Whether user services or market packages are used, the process of selecting and prioritizing the appropriate ITS services for a region is no small task, primarily because of the broad consensus that is required. The process typically involves participation from a wide coalition of stakeholders in a series of meetings before consensus is reached on an accepted set of priority services. Regions that have been through this process and prioritized user services may understandably be hesitant to repeat this process using market packages. Fortunately, there is an alternative approach.

As presented in section 2.3, the user services and market packages are well correlated. This relationship allows a translation between a set of prioritized user services and the equivalent market package prioritization. An example of this translation, derived from the Dallas Early Deployment Plan, is shown in Table 4.2-2. In this example, Table 2.3-2 is altered to organize the user services in the priority order identified in the earlier EDP (or other) analysis. The relationship between user services and market packages identified in the body of the table is then used to translate the user service prioritization into an equivalent market package prioritization that is identified in the left most column in the table.

Note that the market packages are defined to a finer level of granularity than the user services (53 market packages vs. 29 user services). Hence, the market package prioritization that is derived based on the user service - market package relationship should be viewed as an initial prioritization. The finer granularity of the market packages would allow a more refined prioritization of user service sub-elements that are identified separately in the market package definitions. Through this process, a market package plan may be efficiently derived by leveraging the existing user service analysis. In this way, the major metropolitan areas, and any other region with substantial investment in user service analysis, can assess the market packages with minimal rework.

Table 4.2-2: Translating from User Service to Market Package Priorities (Dallas-Area Example)

	User Services																													
	High Priority											Medium				Low Priority														
Market Packages	Pre-Trip Travel Information	Traffic Control	Incident Management	Travel Demand Management	Public Transportation Management	Route Transit Information	Public Travel Security	Highway-Rail Intersection	Hazardous Material Incident Response	Emergency Notification And Personal Security	Emergency Vehicle Management	Route Driver Information	Ride Matching And Reservation	Electronic Payment Services	Board Safety Monitoring	Emissions Testing And Mitigation	Route Guidance	Traveler Services Information	Personalized Public Transit	Commercial Vehicle Electronic Clearance	Automated Roadside Safety Inspection	Commercial Vehicle Administrative Process	Commercial Fleet Management	Longitudinal Collision Avoidance	Lateral Collision Avoidance	Intersection Collision Avoidance	Vision Enhancement For Crash Avoidance	Safety Readiness	Crash Restraint Deployment	Automated Vehicle Operation
High Priority Market Packages																														
Network Surveillance		✓																												
Probe Surveillance		✓																												
Surface Street Control		✓	✓																											
Freeway Control		✓	✓	✓																										
HOV and Reversible Lane Management		✓		✓																										
Traffic Information Dissemination		✓						✓																						
Regional Traffic Control		✓																												
Incident Management System			✓																											
Traffic Network Performance Evaluation		✓		✓																										
Dynamic Toll/Parking Fee Management				✓										✓																
Virtual TMC and Smart Probe Data		✓	✓									✓																		
Transit Vehicle Tracking					✓	✓	✓																							
Transit Fixed-Route Operations					✓	✓																								
Demand Response Transit Operations					✓	✓																								
Transit Passenger and Fare Management														✓																
Transit Security					✓		✓																							
Transit Maintenance					✓																									
Multi-modal Coordination		✓		✓	✓																									
Broadcast Traveler Information	✓					✓						✓																		
Interactive Traveler Information	✓					✓						✓		✓					✓											
Freight Administration									✓																					
Standard Railroad Grade Crossing								✓																						
Railroad Operations Coordination								✓																						
HAZMAT Managment			✓						✓																					
Emergency Response											✓																			
Emergency Routing											✓																			
Mayday Support										✓	✓																			
ITS Planning					✓																									
Medium Priority Market Packages																														
Yellow Pages and Reservation	✓											✓		✓				✓												
Dynamic Ridesharing												✓	✓	✓																
In Vehicle Signing								✓				✓																		
On-board CVO Safety															✓															
Low Priority Market Packages																														
Emissions and Environmental Hazards Sensing																✓														
Advanced Railroad Grade Crossing								✓																						
Autonomous Route Guidance																	✓													
Dynamic Route Guidance																	✓													
ISP Based Route Guidance																	✓													
Integrated Transportation Mgmt/Route Guidance																	✓													
Vehicle Safety Monitoring																												✓	✓	
Driver Safety Monitoring																												✓		
Longitudinal Safety Warning																								✓				✓		
Lateral Safety Warning																									✓			✓		
Intersection Safety Warning								✓																		✓		✓		
Pre-Crash Restraint Deployment																												✓	✓	
Driver Visibility Improvement																											✓			
Advanced Vehicle Longitudinal Control																								✓						
Advanced Vehicle Lateral Control																									✓					
Intersection Collision Avoidance								✓																		✓				
Automated Highway System																														✓
Fleet Administration																							✓							
Electronic Clearance																				✓		✓								
CV Administrative Processes																				✓		✓								
International Border Electronic Clearance																				✓		✓								
Weigh-In-Motion																				✓										
Roadside CVO Safety																					✓									

4.2.2 Estimating Costs and Benefits

Accurate estimates of cost and benefit are critical to the development of a Market Package Plan. In this section, we summarize benefit and cost information from the *Evaluation Results* deliverable

Costs depend not only on the selected implementation and the characteristics of the region, but also on the existing system. For example, the cost of installing a complete Intelligent Transportation Infrastructure (ITI) for Washington, DC has been estimated to be about $277 million. But the actual costs would be lower because the existing infrastucture can be used as a basis for the ITI. Cost estimates in the *Evaluation Results* are incremental, assuming a basic existing infrastructure that forms the basis for new ITS services. Caution should be exercised in using these estimates, and the user must understand the underlying assumptions on which the estimates are based.

A complete cost analysis for several evaluatory designs that illustrate a range of ITS implementations is included in the Evaluation Results. Because the existing infrastructure and needs vary significantly from place to place, a set of spreadsheets for estimating costs was developed to help the architecture team investigate the effects of various cost assumptions and deployment scenarios. The spreadsheets implement the fundamental assumptions and algorithms that could be used as a basis for exploratory cost analysis at the regional level. These spreadsheets were developed specifically for use on the architecture program and have not been crafted with the robust error checking and intuitive user interface necessary for an end-user tool. A refined spreadsheet-based tool could be developed and made available to allow a region to explore what-if scenarios, and to narrow and prioritize options. This effort can be followed by a detailed assessment for the most promising options to obtain more accurate estimates considering local conditions.

Tables 4.2-3 through 4.2-9 show the types of benefits that might be expected from each market package and where these benefits may accrue. This survey of benefits should be considered in conjunction with other benefits assessments for ITS. This general information allows a community to narrow their choice set and subsequently focus their effort on obtaining better benefits estimates for their locality for a reduced set of alternatives.

Table 4.2-3: Benefits of Traveler Information Market Packages

Market Package	Likely Benefits	Context Where Benefits May Accrue
Broadcast Based ATIS	• Possible benefits as high as other interactive ATIS services (see below), depending on capability of in-vehicle devices	• Primary value for incident-related (accidents, weather, special events, etc.) traffic delays, across all geographic areas • Higher benefits to travelers with long trips, multiple mode and route alternatives
Interactive Traveler Information	• Reduction in travel time for equipped travelers • Increases in speeds, decrease in number of stops for equipped travelers • Some benefits for non-equipped travelers • Higher benefits for pre-trip versus on route information • Decreasing benefits with higher market penetrations	• Primary value for incident-related (accidents, weather, special events, etc.) traffic delays, across all geographic areas • Higher benefits to travelers with long trips, multiple mode and route alternatives • Decreasing benefits with higher network loadings (i.e. higher congestion)
Autonomous Route Guidance	• Reduction in travel time for equipped travelers • Increases in speeds, decrease in number of	• Primary value for incident-related (accidents, weather, special events, etc.) traffic delays, across

Dynamic Route Guidance ISP Based Route Guidance Integrated Transportation Management/Route Guidance	stops for equipped travelers • Some benefits for non-equipped travelers • Higher benefits for pre-trip versus en route information • Decreasing benefits with higher market penetrations	all geographic areas • Higher benefits to travelers with long trips, multiple mode and route alternatives • Higher benefits for visitors and other unfamiliar travelers
Yellow Pages and Reservation	• Potential reduction of VMT spent searching for trip destinations	• Benefits highest for visitors and other unfamiliar travelers • Familiar travelers benefit from parking reservation
Dynamic Ridesharing	• Increased vehicle occupancy and use of HOV modes • Improved individual mobility	• Significant density of related trips is necessary to ensure ride matching
In Vehicle Signing	• Reduction in search time and excess VMT • Reduction in accidents	• Anticipated benefits in congested areas, night driving, rural areas • Aid to visually challenged drivers

Table 4.2-4: Benefits of Traffic Management Market Packages

Market Package	Likely Benefits	Context Where Benefits May Accrue
Network Surveillance	• Indirect benefits only • Data support for other ATMS services	• Essential component for incident detection and sometimes for signal control • Higher value for regions where traffic patterns are transient and unpredictable
Probe Surveillance	• Indirect benefits only • Data support for other ATMS services	• Essential component for incident detection and sometimes for signal control • Higher value for regions where traffic patterns are transient and unpredictable
Surface Street Control	• Reduction in travel time • Reduction in queue time • Increase in speeds • Reduction in stops • Reduction in fuel consumption • Reductions in VMT • Reductions in HC and CO emissions • Reduction in intersection-related accident rates, with higher reductions possible for left-turn accidents • Significant benefit-to-cost ratio	• Most surface street systems will benefit from this market package • Cities with major traffic generators such as theme park or stadium will benefit more • It is expected that signal coordination tailored to specific local traffic patterns can have significantly higher benefits
Freeway Control	• Increase in freeway speed (before-after) during congested peak hours, depending on level of congestion • Increase in freeway throughput • Reduction in travel time • Reduction in queue time • Reduction in fuel consumption • Reduction in emissions	
Regional Traffic Control	• Uncertain level of benefits, but can be significant in many instances	• High benefits in regions with many cities or jurisdictions
HOV and Reversible Lane Management	• Largely unknown level of benefits	• Regions that respond by substantial shifts from SOVs to HOVs
Incident Management System	• Reduction in incident response times for large urban areas • FSP programs report significant reductions in incident-related vehicle hours of delay • Significant benefit to cost ratio	• Regions with high frequency of incidents • Regions where incident delays constitute a substantial part of delays
Traffic Information Dissemination	• Positive value but quantitative estimates have yet to be determined	• Regions where travelers respond to traffic information by either changing departure time, route choice, etc. • Regions that have alternate routes, mode choices, etc.
Traffic Network Performance Evaluation	• Reductions in data collection cost • Benefits depend heavily on current surveillance and analysis activities	• Regions that have TDM programs • Regions that have traffic management plans responding to performance evaluation
Dynamic Toll / Parking Fee Management	• Reduce peak hour congestion • Reduction in toll plaza operating costs	

Market Package	Likely Benefits	Context Where Benefits May Accrue
	• Reduced incidents and emissions	
Emissions and Environmental Hazards Sensing	• Reduce incident rate • Improve air quality	• High value in geographic areas in air quality non-attainment
Virtual TMC and Smart Probe		• Assumed value in rural and inter-urban areas with low capital
Standard Railroad Grade Crossing	• Some grade crossing accidents may be avoided	•
Advanced Railroad Grade Crossing	• Some grade crossing accidents may be avoided	•
Railroad Operations Coordination	• Further contribution to benefits identified under Surface Street Control. Level of benefits unknown.	• Larger traffic networks with significant highway-rail intersection closures.

Table 4.2-5: Benefits of Transit Management Market Packages

Market Package	Likely Benefits	Context Where Benefits May Accrue
Transit Vehicle Tracking	• Improvement in vehicle on-time performance • Reductions in field supervision	• Higher benefits to areas with significant transit service reliability problems
Fixed-Route Operations	• Improved productivity of vehicles, labor	• All transit scenarios
Demand-Responsive Operations	• Improved productivity of vehicles, labor • Efficiencies in routing and trip scheduling	• All transit scenarios
Passenger and Fare Management	• Passenger convenience of common fare instrument • Reduction in cash handling losses • Reduction in costs of data collection and fare processing	• Benefits clearest where multiple agencies share services, transfers, etc.
Transit Security	• Faster response to incidents • Record of security incidents	• High benefits in less secure areas (e.g. large urban areas)
Transit Maintenance	• Effective scheduling of maintenance activities • Reduction in maintenance and system repair costs	• All transit scenarios
Multi-modal Coordination	• Reduction in transit travel times from signal priority	• Good institutional cooperation between traffic and transit managers is necessary • Level of benefits depends on ambient traffic volumes and cross traffic in selected corridors or in area-wide systems

Table 4.2-6: Benefits of Commercial Vehicle Market Packages

Market Package	Likely Benefits	Context Where Benefits May Accrue
Fleet Administration	• Improvements in vehicle and driver productivity • Increase in loaded miles	• Local and long-haul systems
Freight Administration	• Largely unknown level of benefits	• Hazardous materials and other sensitive cargo
Electronic Clearance	• Reduction or elimination of border clearance times • Reductions in commercial and public administrative costs • Improvements in vehicle and driver productivity	• Highest benefits for long-haul carriers
Commercial Vehicle Administrative Processes	• Significant cost savings for commercial vehicle operators and regulatory agencies	
International Border Electronic Clearance	• Reduction or elimination of border clearance times • Reductions in commercial and public administrative costs • Improvements in vehicle and driver productivity	• Highest benefits for long-haul carriers
Weigh-In-Motion	• Reduction in vehicle weighing times • Reductions in commercial and public administrative costs • Improvements in vehicle and driver productivity	• Highest benefits for long-haul carriers
Roadside CVO Safety	• Reduction in safety inspection times • Reduction in commercial vehicle accidents	

Market Package	Likely Benefits	Context Where Benefits May Accrue
On-board CVO Safety	• Reduction in commercial vehicle accidents	
CVO Fleet Maintenance	• Improvement in vehicle productivity • Reduction in commercial vehicle accidents	
HAZMAT Management	• Faster and more appropriate response to HAZMAT incidents	

Table 4.2-7: Benefits of Vehicle Safety Market Packages

Market Package	Likely Benefits	Context Where Benefits May Accrue
Vehicle Safety Monitoring	• Lower vehicle maintenance costs • Lower accident and vehicle breakdown rates	
Driver Safety Monitoring	• Lower accident rates due to driver impairment	
Longitudinal Safety Warning	• Reduction in backing and rear-end accidents	
Lateral Safety Warning	• Reduction in lane departure accidents	
Intersection Safety Warning	• Difficult to estimate level of reduction of intersection-based accidents • Some intersection-related accidents may be avoided	• Higher possible value at unsignalized intersections
Pre-Crash Restraint Deployment	• Reduction in accident severity	
Driver Visibility Improvement	• Reduction in accidents due to driver vision impairment • Reduction in night vision impairment accidents	• Higher benefits in night driving, inclement weather • Significant benefits for visually challenged drivers
Advanced Vehicle Longitudinal Control	• Improvement in highway lane capacity • Reduction in rear-end and backing accidents with other automobiles • Reduction in rear-end and backing accidents with fixed objects	• Applications most likely on freeway and other restricted-access roads
Advanced Vehicle Lateral Control	• Reduction in lane departure accidents	• Applications most likely on freeway and other restricted-access roads
Intersection Collision Avoidance	• Unknown level of benefits, difficult to quantify	• Possible high value at unsignalized intersections
Automated Highway System	• Significant improvements in highway lane capacity • Broad range possible safety and environmental benefits, depending on system design	• Likely scenarios still under discussion

Table 4.2-8: Benefits of Emergency Management Market Packages

Market Package	Likely Benefits	Context Where Benefits May Accrue
Emergency Response	• Assumed reduction in response times through system-coordinated response	• Higher level of benefit realized in areas with multiple jurisdictions and independent response agencies
Emergency Vehicle Routing	• Unknown level of benefits	
Mayday Support	• Anticipated faster routing of calls, shorter response times	• Higher level of benefit realized in areas with multiple jurisdictions and independent response agencies • High benefits in rural areas

Table 4.2-9: Benefits of ITS Planning Market Package

Market Package	Likely Benefits	Context in which Benefits May Accrue
ITS Planning	• Largely unknown level of benefits; rarely measured in quantitative terms • Potential reduction in effort required for data collection and analysis for system planning • Coordinated system planning may yield more efficient use of funding and other resources	• Institutional relationships at a regional level must be sufficient to facilitate cooperation between different agencies and jurisdictions

4.3 Defining a Regional Architecture

Once a Market Package Plan has been developed that documents the ITS services that should be deployed in a region, the regional framework in which these services will be deployed should be defined. The National Architecture provides a general framework that may be adapted and elaborated into a broad range of regional transportation system designs. A regional architecture is a key product of this process that begins to overlay major technology and interface choices which are appropriate for the region onto the more general National Architecture definition.

Adoption of a regional architecture hinges on continued coordination and consensus among involved stakeholders. In many cases, the regional policy decisions, such as agreeing on the level of coordination or connectivity desired, will be more difficult than development of a technical framework that supports the desired systems integration over time. Both technical and non-technical implications of a regional architecture are addressed in this section.

4.3.1 Opportunities and Challenges

Systems integration, if achieved, has the potential to increase the benefits of ITS. Unfortunately, there has been relatively little field experience with broadly integrated systems to draw on to quantify these benefits. The integration that has taken place in areas such as Los Angeles and Chicago is believed to have provided significant benefits. The expected benefits of systems integration include:

(i) Benefits through system coordination and synergy

Integration, especially between traffic, transportation, and transit operation centers, may result in the following benefits:

- Improved data collection and utilization: an integrated transportation management system may reduce costs of obtaining, processing, and disseminating data, because of reduced duplication of effort and increased sharing of information.
- Improved system performance: Traffic congestion, energy consumption, and air pollution may be reduced as a result of synchronized operations, such as smoother traffic flow, faster incident response, and coordinated traffic diversion plans.
- Increased reliability of the overall transportation system: An integrated system facilities the development of a set of coordinated plans and procedures to handle different incident situations.

- Enhanced opportunities for cooperation: Productive, cooperative partnerships between public sectors, and between public and private sectors, may be promoted by having a common platform to discuss and resolve issues.

(ii) Benefits through coordinating modal information and operations

Intermodal services, by definition, require the coordination of various transportation modes. An integrated system may reap benefits in these ways:

- Increased accessibility to all modes: Utilization of underused transportation modes (e.g., transit) can be promoted by improving modal connectivity. This results in more attractive modal choices, increased travel flexibility, higher travel quality, and greater travel convenience.
- Improved system performance: Traffic congestion, energy consumption, and air pollution may be reduced through increased utilization of high occupancy vehicles (shuttles, buses, etc.), and decreased reliance on private automobiles. This also permits reduction in transit travel time as a result of faster transfers.
- Reduction in travel cost: Better utilization of transit reduces per passenger costs and reduces vehicle delay during congested periods by reducing the number of vehicles using the roads.
- Increased reliability: Improvement in connectivity makes transit a more attractive mode choice, thus increasing transit use and reducing vehicle volumes, travel time, and variance in travel time.
- Enhanced opportunities for cooperation: Increased coordination is likely to enhance awareness of further opportunities for cooperation and to provide a structure for realizing these opportunities.
- Improved productivity: Where intermodal freight movements are facilitated by coordinated information and operations, shipping time and cost can be reduced.

There are a number of recent studies that look at the benefits of integrating different traffic management functions, such as between ramp metering and arterial signal control (City of Irvine and Orange County in California), between route guidance and signal control (FAST-TRAC in Detroit, Michigan), and between different traffic signal systems (San Jose, California).

However, such integration is not without costs. Staff time is required to resolve conflicting objectives and reach compromises regarding hardware, software, and management choices, all within financial constraints. The most difficult challenge of transportation systems integration is the diversity of involved stakeholders and the range of interdisciplinary activities that must be coordinated to develop, deploy, and operate ITS. These activities can be initiated and pursued by a variety of public and private sector institutions and influenced by variety of stakeholders, special interest groups, and the general public, which is the ultimate customer of ITS services. Table 4.3-1 highlights the range of actions that can be necessary to achieve a regional, integrated system, and the variety of stakeholder groups that can be associated with each activity. In the following, we comment on issues for bringing that about, and on how the national ITS architecture can assist in this process.

Table 4.3-1: Possible Actions and Players in Integrated Transportation Management

Planning and Policy	**Sample Stakeholder Groups**
Establish regional ITS forums	AAA, AARP, ATA, AQD, APD, COs, SDOT, CDOT, DMV, HP, ISP, MTC, MPO, TMA
Define jurisdictional boundaries and responsibilities	AQD, APD, COs, SDOT, CDOT, HP, MTC, MPO, TMA
Define local needs	AAA, AARP, ATA, APD, COs, SDOT, CDOT, DMV, ISP, MTC, MPO, TMA
Review local plans	AQD, COs, SDOT, CDOT, ISP, MTC, MPO, TMA
Develop ITS-compatible operating strategies	COs, SDOT, CDOT, HP, ISP, MTC, MPO, TMA
Identify locally needed R&D	COs, SDOT, CDOT, MTC, MPO, TMA
Promote public-private partnerships.	AAA, ATA, APD, COs, SDOT, CDOT, ISP, MTC, MPO, TMA
Develop procedures for franchises	ATA, COs, SDOT, CDOT, ISP, MTC, MPO, TMA
Deployment and Operation	
Coordinate with operating agencies	ATA, APD, SDOT, CDOT, DMV, FMC, HP, ISP, MTC, MPO, TMA, RR
Choose suitable market packages	SDOT, CDOT, TMA
Define and regulate access to and control of public right-of-way	APD, COs, SDOT, CDOT, MTC, MPO, TMA, RR
Define and regulate access to and control of TOC's	SDOT, CDOT, TMA
Plan and execute FOTs	ATA, AQD, APD, COs, SDOT, CDOT, HP, ISP, MTC, MPO, TMA
Choose regional interoperability standards	SDOT, CDOT, TMA, RR
Define local RF spectrum allocation	SDOT, CDOT, TMA
Decide interfacing standards	SDOT, CDOT, TMA, RR
Establish a design of a standard TMC	SDOT, CDOT, TMA
Devise incident response strategies	SDOT, CDOT, HP, ISP, MPO, TMA
Devise traffic diversion policies and plans	SDOT, CDOT, HP, ISP, MPO, TMA
Formulate ramp metering policies and control plans	SDOT, CDOT, HP, MPO, TMA
Devise signal coordination and control plans.	SDOT, CDOT, HP, MPO, TMA

Sample Stakeholders:

AAA:	American Automobile Association	**FMC:**	Freight Management Center
AARP:	American Association of Retired Persons	**DMV:**	Department of Motor Vehicles
ATA:	American Trucking Association	**HP:**	Highway Patrol (and local traffic patrol)
AQD:	Air Quality District	**ISP:**	Information Service Provider
APD:	Airport District	**MTC:**	Metropolitan Transportation Commission
COs:	Counties	**MPO:**	Metropolitan Planning Organization
CDOT:	City Department of Transportation	**TMA:**	Transit Management Authority
SDOT:	State Department of Transportation	**RR:**	Railroads

4.3.2 Adapting the National Architecture for Regional Use

The National ITS Architecture is based on a comprehensive functional analysis supporting all defined user services and provides a natural framework for integrating local systems and developing a regional architecture. To develop an appropriate framework, a region must first identify the institutions and transportation management functions to be included and the degree of coordination sought. Beginning with the national architecture, a regional architecture can then be developed to reflect these requirements. The regional architecture adds a level of specificity that the national architecture lacks by balancing local conditions and existing infrastructure with newly planned functions and infrastructure. This section provides guidance for applying the National Architecture to this process. The discussion addresses application of both the Transportation Layer and Communications Layer elements of the National Architecture definition. Refer to section 2 for background on the National Architecture definition.

The federally sponsored EDP process has initiated regional architecture development for the largest Metropolitan Areas in the country. Hence, many communities already have documented regional architectures that were developed prior to the National Architecture. If a regional architecture already exists, this architecture can be compared against the National Architecture framework. If a regional architecture does not exist, it can be developed with consideration for the National Architecture products from inception.

An underlying issue in this process is that a product that is new to the regional planning function is developed: A regional architecture. The regional architecture is a concise, formal statement of the architecture choices made by the region. It documents the selected interface standards, regional configuration, and consensus technology choices that will support competitive procurement of systems within the region. It should be developed and maintained as a product open to industry, agency, and public scrutiny and comment. Configuration management principles should be used to maintain control over this architecture as it is adopted and subsequently evolves and changes. The activities associated with developing and maintaining a regional architecture are rewarded through the benefits of open and interoperable systems within the region.

The regional architecture represents a middle ground between regional planning and project implementation that requires diverse expertise that is not likely to be held by any single public agency or consultant in the region. As a focal point for regional planning, the Regional Transportation Authority (MPO in Metropolitan Areas) may be a logical organizational choice to manage the development and maintenance of a regional architecture. Where the Regional Transportation Authority is not well suited to these tasks, an alternate agency or other designee may be more appropriate. As with other regional plans, ample opportunity for input should be afforded to the various stakeholders in the region throughout the process. The decisions that lead to an appropriate regional architecture may be reviewed in the context of a steering committee including affected stakeholders and with support from a consultant.

It is useful to note that the integration approach identified in the regional architecture may be implemented in steps. New systems should be required to support currently available open standards identified in the regional architecture to facilitate future integration with other systems when the need arises. Existing systems that are proprietary or otherwise do not lend themselves to regional integration can continue operation as isolated systems until lifecycle cost considerations suggest replacement or a compelling regional need dictates retrofit or replacement. Each region must decide whether, or the degree to which, their system will be consistent with the National Architecture. This involves cost-benefit considerations, and perhaps also federal policies in encouraging such consistency where national interoperability implications are greatest. The National Architecture may be viewed as a tool that can be used to facilitate development of a regional architecture and interoperable transportation systems within the region.

4.3.2.1 Using the Transportation Layer

As a preliminary step in applying the National Architecture to the region, the existing and near-term (currently programmed) transportation systems are mapped to the subsystems and terminators defined by the National Architecture. This mapping requires a high-level understanding of the National Architecture elements and the regional systems to establish the mapping between equivalent elements. An existing or planned interface between two regional transportation systems becomes an interface between two subsystems or between a subsystem and a terminator in the National Architecture mapping.

Figure 4.3-1 illustrates a sample mapping between the Southern California Showcase Program and the National Architecture. As can be seen from the figure, the Showcase Program includes an especially aggressive integration effort that encompasses a host of agencies and systems over a broadly distributed five county region covering much of Southern California. Due to the number and diversity of systems involved, only a representative set of the included agencies are shown in the figure. Also, multiple traveler information access points will be available to travelers in the region. Only one of these projects (the TravelTIP project in Orange County, CA) is shown in the figure as a representative example of the way public and private information providers will integrate into the Showcase Architecture.

Even for more modest integration efforts, the regional architect should strive to be inclusive in the initial stages of regional architecture definition so that potential interface requirements are not overlooked. For instance, even those agencies that currently operate relatively modest or manual systems (e.g., small municipalities within a metropolitan area that currently operate fixed timing traffic control systems) should be included as potential interfaces. Through this general mapping process, the interface definitions from the National Architecture may be applied to the existing and planned transportation systems in the region.

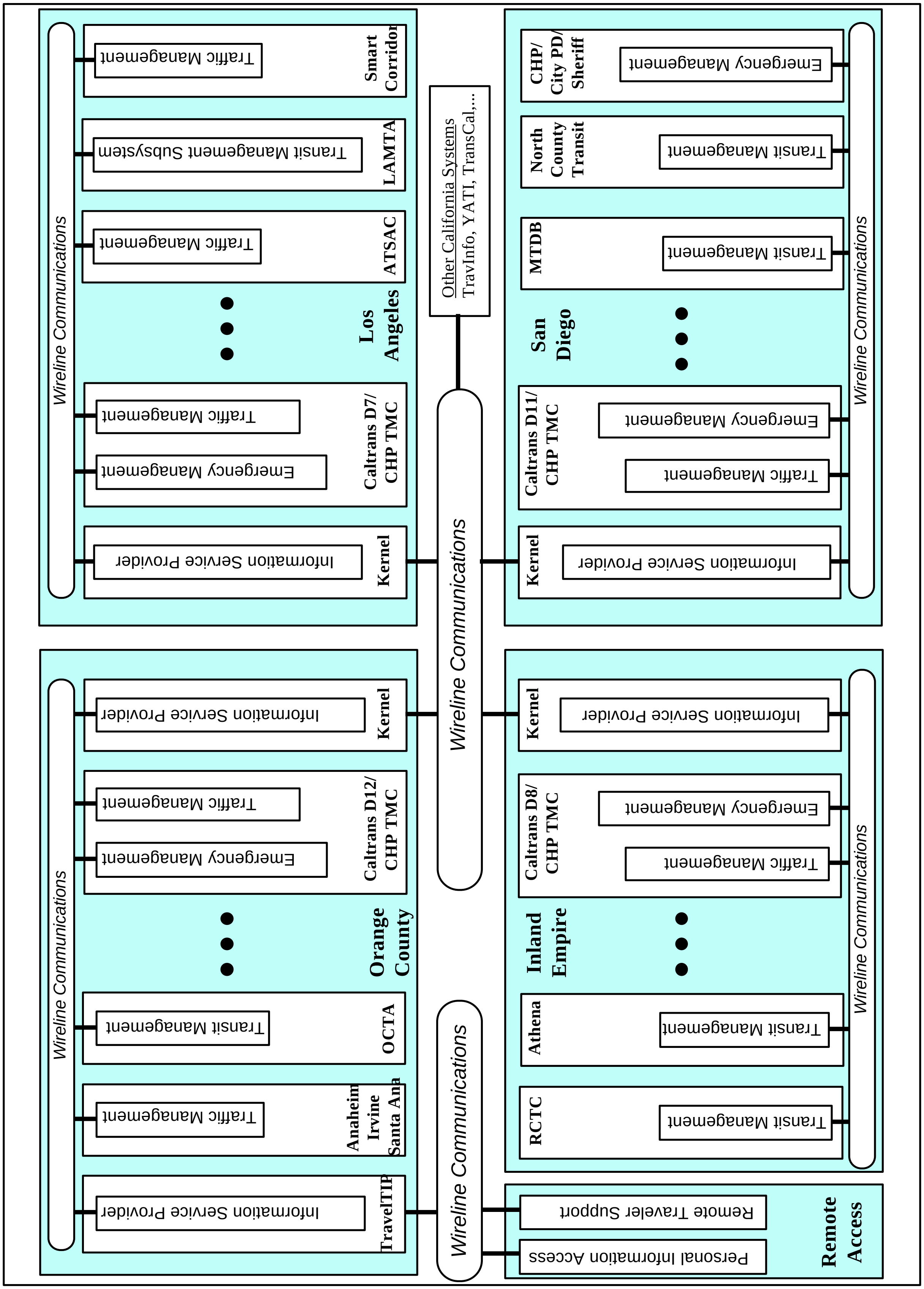


Figure 4.3-1: Southern California Showcase Prototype Architecture Mapping

In many cases, the regional plan will also include new services that are not addressed by the National Architecture. For instance, the regional plan might include advanced road maintenance systems that are not directly supported. A traditional systems engineering process may be used to translate the general statement of these improvements in the Market Package Plan into the specific system requirements and architecture features that are required to support the improvement. The extended requirements that are identified may be mapped into the regional architecture as new subsystems and interfaces or as new capabilities and interface requirements to be supported by the regional architecture framework.

The end-result of this process is a regional architecture that includes existing systems and reflects necessary extensions to these systems and their interfaces to support the new transportation services that are planned for the region. The process provides a mechanism for selectively applying the details from the National Architecture definition to the regional architecture and system designs it supports. The National Architecture definition provides a wealth of information that can expedite and assist portions of the rigorous systems engineering effort normally associated with architecture development. For instance, the subsystem definitions in the *Physical Architecture* identify the functional requirements that can be applied to each of the mapped transportation systems. The *Physical Architecture* also identifies the required message elements (architecture flows) and any special constraints (e.g., special performance or reliability, security, or privacy constraints) associated with each of the interfaces. The *Logical Architecture* provides a more detailed specification of the functions that are performed by each subsystem (the process specifications or p-specs) and the data elements that are shared by each of these functions as ITS services are provided. The architect or designer who requires this level of detail may find it in the *Logical Architecture*

4.3.2.2 Using the Communication Layer

Once the transportation systems that will support a region's future transportation needs have been identified, the communication architecture that will integrate these systems must be defined. The development of a communication architecture comprises a set of steps which, more or less, parallel those of a generic system architecture. A few basic steps can be identified. The first is the development of the communication services description, using widely accepted conventions. (Communication services are generic information transfer capabilities, such as conversational speech or messaging data). The detailed definition of the communication service is based on the communication needs of the various transportation systems. The second step in the development of a communication architecture is determining the network's logical functions (e.g., wireless access, registration) to meet the requirements of the communication service. The third step has two elements: the first is the identification of the functional entities (e.g., switch, base station) that can be used to perform the logical functions, and the second is matching those functional entities to established or revised network reference models, which identify reference interfaces between the physical equipment (standards are usually written for those reference interfaces.)

This framework has been used often, in developing new telecommunication services and systems with open specifications, such as cellular (AMPS, GSM, CDMA, CDPD, etc.), PCS, and others. The same approach has been used in defining the Communication Layer of the National ITS

Architecture. The Communication Layer definition and supporting analyses are a useful resource that can facilitate development of a communication architecture for the region.

As briefly described in section 2.1.2 of this document and more thoroughly defined in the separately-bound *Communications Document*, the Communication Layer of the National Architecture shows how various communications technologies can be used to support the communications requirements for ITS. The Communication Layer definition includes an implementation-independent description of the general communications services and media types that connect the transportation subsystems in the Transportation Layer.

The Transportation Layer and Communication Layer are connected since each data flow defined in the Transportation Layer has an associated communications service and interconnect definition in the Communication Layer. The information from the Communication Layer may be applied to the regional architecture by extending the mapping performed in section 4.3.2.1 to follow these connections and include the appropriate interconnect and communications service definitions.

Broad choices are preserved for the local implementor in the National Architecture Communication Layer definition. In many cases, the data flows defined in the Transportation Layer can be supported in several different ways by the Communication Layer (e.g., basic traveler advisories may be provided through both wide area wireless and dedicated short range communications interconnects). The Communication Layer does not favor a particular communication technology or prescribe the fundamental choice between use of public and private networks for ITS communications. Specifying the communications component of the regional architecture consists of beginning to make some of these choices based on local service needs, local experience, and the status of the local telecommunications infrastructure.

Many of the fundamental choices that can be addressed in the Regional Architecture are highlighted as “Architecture Renditions” in the Communications Document. The Architecture Renditions are examples of how to provide connections between users based on feasible implementations that are consistent with the Communications Layer definition. Figures 4.3-2, 4.3-3, and 4.3-4 show two levels of renditions to illustrate the choices that may be reflected in a regional architecture or, alternatively, preserved for the system designer. Note that the renditions do not make technology choices but do begin to enumerate the technology and system options that are available and the way in which interoperability would be established between these options.

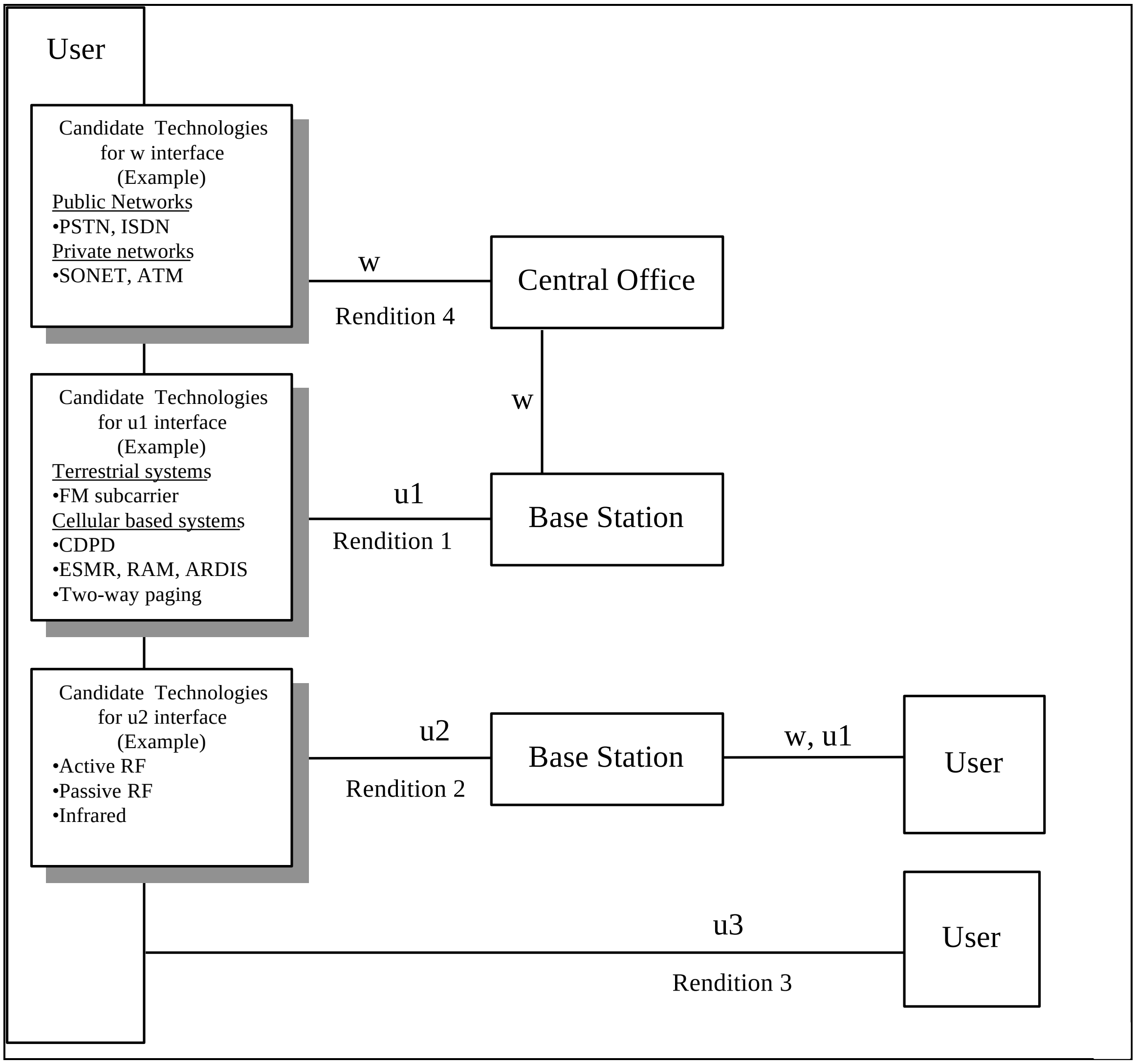


Figure 4.3-2 Level 0 Rendition

The Level 0 rendition shows the full connectivity between users over multiple links. It shows a user communicating to another user, central office or a base station over various wireline and wireless communications links defined as u_1, u_2, u_3 and w in the Communications Document.

A Level 1 rendition is provided in the Communications Document for each of the interconnections in the Level 0 Rendition. These more detailed renditions are important to the regional architect who has decided to implement a dedicated communications system or support a mix of dedicated systems and purchased communications services and requires a general communications architecture framework to guide this development. Figure 4.3-3 depicts more detailed renditions for the two-way wide-area wireless communication link (u_1) using switched networks. This figure depicts interconnection between tetherless users or tetherless and stationary users, utilizing two distinct classes of two-way wide-area wireless technologies. Several technologies or systems support each rendition. For example, CDPD, RAM, and ARDIS are all potential candidates for implementing the packet-switched wireless data network rendition (shown on the right-hand-side of the diagram). Figure 4.3-4 depicts the rendition for the one-way wide area wireless link u_{1b}.

It uses broadcast systems which include paging and FM subcarrier technologies for transmitting data to subscribers over the paging and FM frequency channels, respectively.

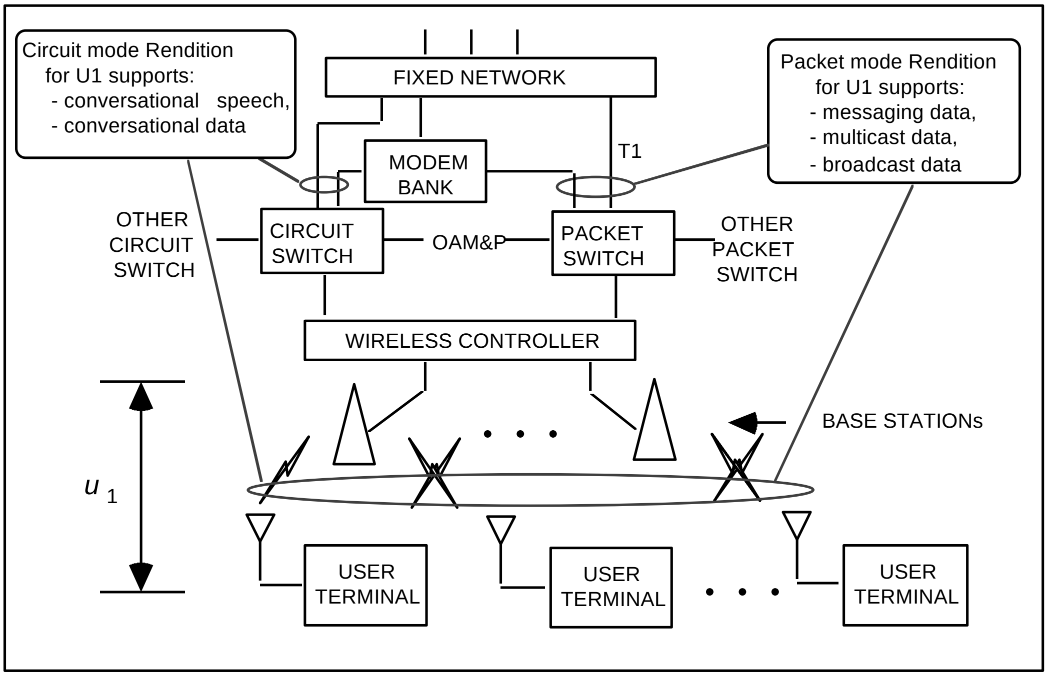


Figure 4.3-3 Rendition for Two-way Wide-Area Wireless (u1) Links

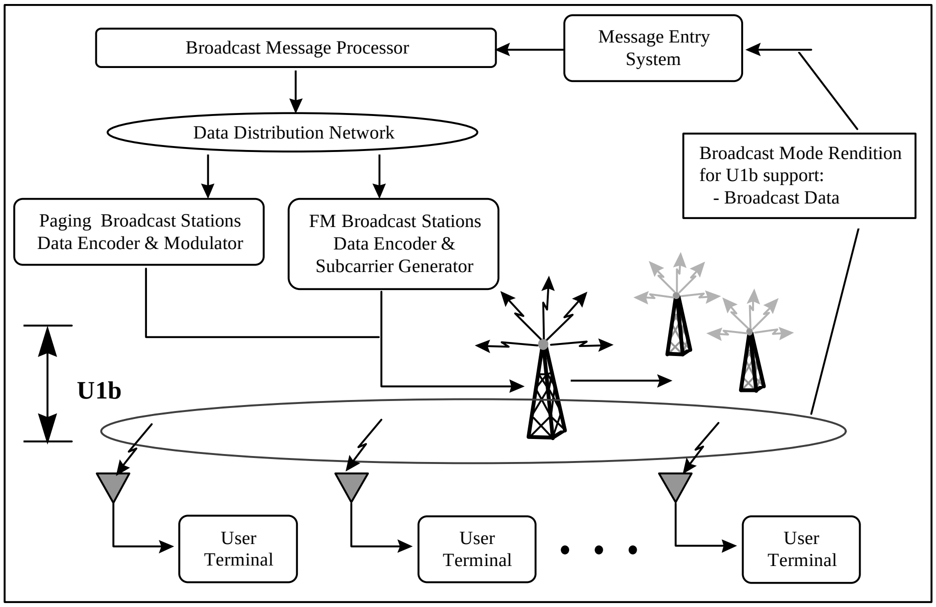


Figure 4.3-4 Rendition for One-way Wide-Area Wireless (u1b) Links

Where possible, the choice of a communications system or technology should be reserved until system implementation rather than dictated as part of a regional architecture. Rapid advances in communications technology and available service choices can make today's best communication solution tommorrow’s underdog. Section 4.5 provides a general characterization of the currently available communication technologies to support these implementation decisions.

4.3.3 Standards Implications of the National Architecture

Once a regional framework is developed that maps the transportation systems, operating agencies, and communications infrastructure for the region into the subsystems and communications interfaces identified by the National Architecture, standards requirements from the National Architecture can be associated with each of the regional interfaces.

The National Architecture generally reserves its standards recommendations for interfaces between major systems or agencies. This means that interfaces within a particular system (e.g., within a transit management system or within a transit vehicle) are not dictated by the National Architecture. Aligning the Regional Architecture with the National Architecture principally involves applying and fine tuning the requirements for the major system interfaces.

To present the standards implications of the National Architecture, this section provides a fairly detailed review of the Interoperability Assignments (National, Regional, Product, and None) that have been made for each of the interfaces defined by the Architecture. The basic definitions for these interoperability assignments follow:

1. *National Interoperability.* Interfaces to the mobile subsystems (Vehicle Subsystems, Personal Information Access Subsystems) in the architecture support national interoperability since the same mobile subsystem should be able to roam the nation and use the local infrastructure to support ITS services. National interoperability is specified for all interfaces to mobile subsystems except where both the mobile subsystem and interfacing infrastructure are owned and operated by the same user. Examples of these include the Information Service Provider to Personal Information Access Subsystem, Toll Collection Subsystem to Vehicle Subsystem, and the Commercial Vehicle Subsystem to Commercial Vehicle Check Subsystem.

2. *Regional Interoperability.* Interfaces connecting subsystems that may be operated by different agencies (interfaces that can span jurisdictional and/or regional boundaries) can be standardized to facilitate the sharing of information between agencies. National standards mitigate issues that may arise as boundaries change and new requirements for information sharing develop over time. Regional interoperability is specified where the underlying coordination issues are regional, rather than national, in scope. For instance, there is no real requirement for a Traffic Management Subsystem in California to be able to communicate and coordinate with a Traffic Management Subsystem in New York. Two different regional dialects for Traffic Management Subsystem communications could be implemented in the two geographically isolated subsystems, without significant impact to national interoperability goals. Examples of these include the Traffic Management Subsystem to Transit Management Subsystem, Traffic Management Subsystem to Information Service Provider, and Traffic Management Subsystem to Traffic Management Subsystem.

3. *Product Interoperability.* Interfaces between subsystems that are operated and maintained by a single stakeholder (e.g. company or agency) do not require standardization to achieve

national interoperability. The data formats and communications mechanisms that are used for these interfaces are largely transparent to the remainder of the architecture. In some cases, national standards are still very beneficial (and hence still attainable through the consensus standard process) since they may consolidate a market to achieve economy of scale efficiencies (e.g. Traffic Management Subsystem to Roadway Subsystem). If multiple agencies adopt the same Product Interoperability standards within a region, future implementation of various shared resource and cooperative control strategies will be facilitated.

4. *No Interoperability Requirement.* In other cases, the sheer range of application-specific interfaces precludes efficient national standardization and no standard is suggested. For instance, a national standard is not recommended for the interface between the Fleet Management and Commercial Vehicle subsystems since the nature of the interface is so dependent on fleet type. From the National Architecture perspective, standardization for these interfaces is not suggested. Examples include the Fleet Management Subsystem to Commercial Vehicle Subsystem.

Note that there is a distinction between the “rationale” for standardization that is itemized above and the priority of the standard which relates to urgency (time criticality) and importance (the level of economic benefit that is anticipated from the standard by interested stakeholders).

The standards requirements that are identified by the National Architecture are one step in the process towards realization of consensus ITS standards. These standards will actually be developed by standards development organizations (e.g., NEMA, SAE, IEEE) using an open process with active participation by private industry and public agency stakeholders. The resulting consensus standards will then be available to the transportation system developer for use in procurement of new systems and upgrade of existing systems. Adoption of these standards encourages interoperability between systems and enables insertion of new technologies over time. The standards can also provide the private sector access to broader markets and encourage competition among suppliers to reduce the cost of traffic management procurements.

Once the standards are available, adapting the regional architecture to be consistent with the National Architecture involves a relatively straight-forward mapping between the major interfaces defined by the National and Regional Architectures. The standards requirements levied by the National Architecture may then be allocated to the Regional Architecture interfaces.

Figure 4.3-5 illustrates this process for the Dallas area. In the example, the interoperability assignments identified by the Architecture are allocated to the Dallas area operating agencies, other transportation stakeholders, and existing and proposed systems. Note that this mapping reflects selection of NTCIP as the standard for communications between the traffic management and roadside elements in the Dallas area. Where standards have not been adopted for the region, the National Architecture interoperability rating (National or Regional, see section 2.6 for more information) is shown in this mapping. Other standards can be applied to the regional framework as they become available and are adopted for the region.

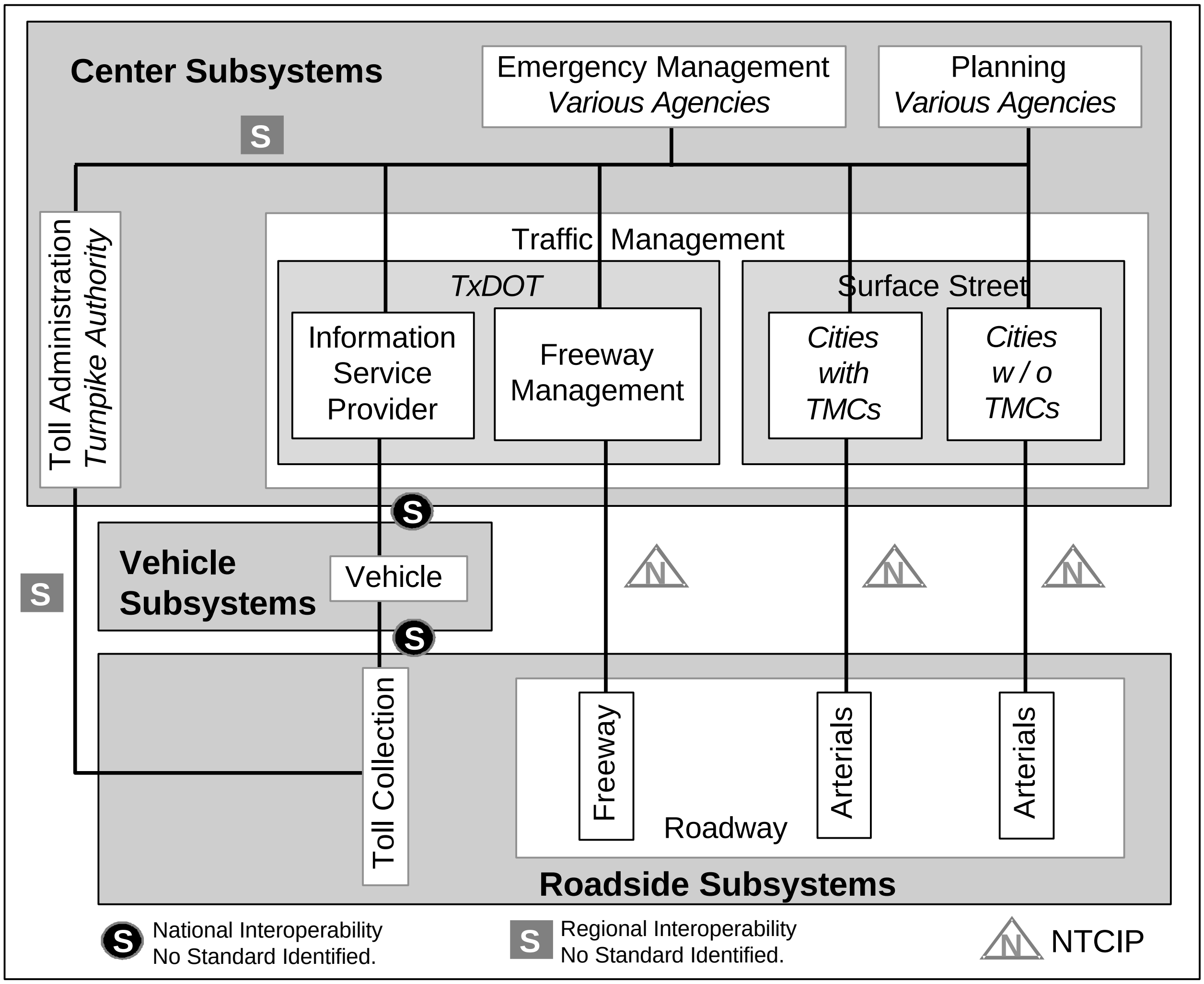


Figure 4.3-5: Mapping Standards Requirements to the Regional Architecture (Dallas Example)

The promise of future standards may motivate potential implementors to wait until the standards are adopted before implementing transportation services, out of fear of being saddled with a system that is not supported by the new standards. This is likely to be a bigger issue for marginal applications than for those where large benefits are expected. If the expected benefits are large enough, an agency is likely to take the risk of developing a system that may not prove compatible with the standards that are eventually adopted. In San Jose California for example, neighboring cities are trying to join the traffic management system that San Jose installed in 1990. The agency with the greatest need led the way, and other agencies are following, yielding a measure of regional standardization. Even non-compliant systems, if built with an understanding of the interoperability requirements included in the National Architecture, will be much easier to interface to than will systems that do not take these issues into account.

Standard requirements defined by the National Architecture that are pertinent to each major stakeholder area are summarized in the remainder of this section.

4.3.3.1 Standards Requirements for Traffic Management

Figure 4.3-6 shows the standards assignments identified within the national architecture which facilitate development, operation, and maintenance of advanced, integrated traffic management systems.

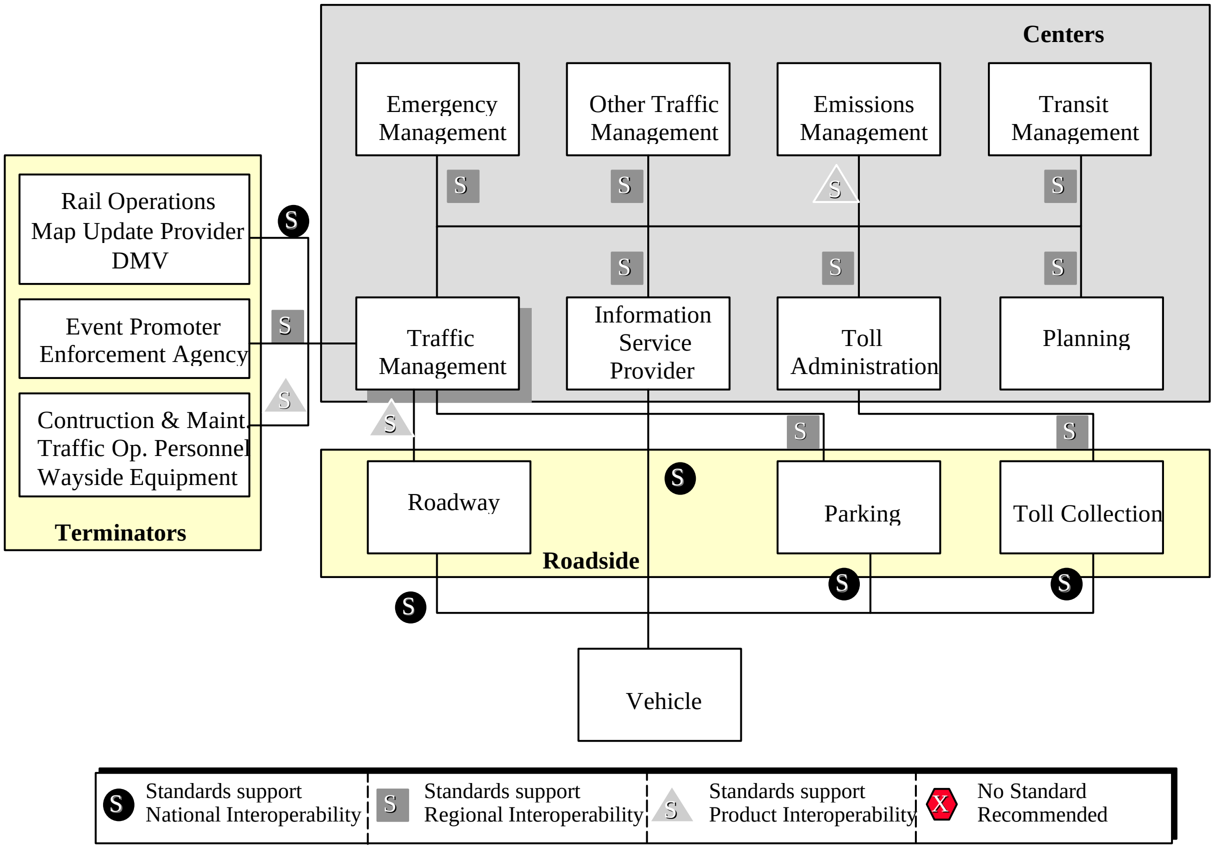


Figure 4.3-6: Traffic Management Standards Requirements

The identified standards may be described in three general categories:

1. *The interfaces between the Traffic Management Subsystem and the other centers.* These interface standards support the sharing of traffic information and control strategies between traffic management agencies, sharing of traffic information with various information service providers, and coordination with emergency management agencies and rail operations.
2. *The intra-agency interfaces between the Traffic Management Subsystem and Roadway Subsystem, and the Toll Administration Subsystem and Toll Collection Subsystem.* The Traffic Management Subsystem interface includes all communications between a traffic management center and its associated field elements. The NTCIP standard covers all communications on this interface that are required to implement the early market packages identified in section 2. The interoperability issues addressed by this standard are local to a particular agency. It may be advantageous to incorporate this standard(s), but no national mandate or conditional federal funding is expected to be tied to its adoption.

3. *The interfaces to the Vehicle Subsystem.* Direct, short range communications between the vehicle and the roadway and wide area communications with the vehicle support collection of probe data and provide in-vehicle signing information to vehicles.

Additional definition for each of the identified standards interfaces is provided in table 4.3-2. Refer to the separate Standards Development Plan and Standards Requirements Document deliverables for additional information.

Table 4.3-2: Traffic Management Standards Requirements Overview

Interface	Supports Market Package	Description	Standardization Benefit
Vehicle to S Roadway	• Traffic Information Dissemination • In-Vehicle Signing	Short range communication of location specific sign information for in-vehicle presentation.	Common interface reduces number of distinct, short range vehicle interfaces. Consistent performance across regions a significant safety consideration for in-vehicle signing.
S Information Service Provider	• Probe Surveillance	Equipped vehicle reports current traffic and road conditions via wide area wireless communications at pre-determined points in trip itinerary, by exception, or on special request.	Common interface increases the available population of probes improving data fidelity and network coverage.
S Toll Collection	• Dynamic Toll/Parking Fee Management • Probe Surveillance	Two-way, short range communications between an in-vehicle tag and roadside beacon supporting automated billing/debiting at speed. Interface definition also supports probe data collection.	Common interface is a traveler convenience and improves operational efficiency. Alternative source for traffic information.
S Parking Management	• Dynamic Toll/Parking Fee Management	Two-way, short range communications between an in-vehicle tag and roadside beacon supporting automated billing/debiting as vehicles enter or exit a parking facility.	Common interface for parking facilities and other toll facilities is a traveler convenience and improves operational efficiency
Traffic Mgmt to S Emergency Management	• Incident Management System	Exchange of incident status information supporting early identification and rapid and appropriate coordinated response.	Standard facilitates interoperability between diverse response agencies and potentially distributed traffic management centers within a region.
S Traffic Management	• Regional Traffic Control	Exchange of traffic information, advisories, and control data between traffic management subsystems. Supports coordination between neighboring jurisdictions and between freeways and arterials.	Many agencies and jurisdictions may be integrated in institutionally complex metropolitan areas. Standard reduces development costs as existing autonomous systems are integrated and new systems are brought on-line.
S Information Service Provider	• Probe Surveillance • Network Surveillance • Regional Traffic Control	Initially enables sharing of real-time traffic information. Interface supports transfer of raw traffic data, processed measures of effectiveness, with associated data quality attributes. Advanced service shares OD pairs enabling system optimal strategies.	Facilitates entry and competition among private information providers enhancing service to travelers and revenue opportunities for traffic management subsystems.
S Emissions Management	• Emissions and Environmental Hazards Sensing	Coordination between emissions management and traffic management subsystems enabling rapid response to detected hot spots.	Product Interoperability is recommended due to limited number of involved parties in a region. However, this standard interface may be replicated in numerous non-attainment regions pooling knowledge and saving development costs.
S Toll Administration	• Probe Surveillance • Dynamic Toll/Parking Fee Management	Provides traffic information to the TMS. Pricing data is coordinated for variable pricing mechanizations.	Standard interface may be replicated to reduce development costs in regions with multiple toll authorities and traffic management jurisdictions.
S Planning Subsystem	• Traffic Network Performance Evaluation	Off-line transfer of daily traffic information to support on-going evaluation, planning, and research activities .	Provision for standard archival facilitates development and application of standard planning support tools. Facilitates area-wide and comparative analyses.

Interface	Supports Market Package	Description	Standardization Benefit
🅂 Parking Management	• Dynamic Toll/Parking Fee Management	Current parking availability data provided to TMS to enable strategies tailored to current parking as well as traffic conditions in urban centers.	Standard interface may be replicated to reduce development costs in regions with multiple parking authorities and traffic management jurisdictions.
Ⓢ Map Update Provider	• All services	Spatial data transfer standard enabling off-line sharing/update of map data used within the traffic management subsystem.	Facilitates sharing of centrally maintained map data while allowing individual applications within the region to select the GIS best suited to their needs.
Ⓢ Rail Operations	• Standard Railroad Grade Crossing • Advanced Railroad Grade Crossing • Rail Operations Coord	Coordination between systems responsible for highways and railroads makes pertinent rail operations schedules available to the traffic manager and enables sharing of status concernng highway-rail intersections.	Standard interface facilitates sharing of data between regional and local traffic management systems and railroad systems which are often national in scope.
🅂 Event Promoter and Enforcement Agency	• Incident Management • Traffic Information Dissemination	Traffic management is enhanced by linking with event promoter and enforcement agencies to establish coordination plan for big events.	Regional interoperability is recommended because region-wide coordination is needed for managing traffic for big events. This standard will facilitate communication between traffic generators with TMCs.
△ Traffic Management to Roadway	• Network Surveillance • Surface Street Control • Freeway Control • Regional Traffic Control • HOV and Reversible Lane Management • Incident Management System • Traffic Info Dissem, • Emissions and Environ. Hazards Sensing	Supports communication between traffic management center and distributed field elements on or near the roadway. Traffic and road condition information collected by roadside detectors transferred to TMS. Traffc control parameters transferred to roadside effectors (CMS, ramp meters, signals, cameras). Enables remote test and background status monitoring of all roadside equipment.	Standardization is anticipated to be a major enhancement in day to day operation and maintenance of systems facilitating maintenance of spare inventories and enhancing competition among infrastructure suppliers.
△ Roadway to Wayside Equip	• Standard Railroad Grade Crossing • Advanced Railroad Grade Crossing	Establishes communications between field elements that monitor and manage rail traffic and highway traffic for purposes of integrated and safe highway-rail intersection operation.	Standardization will enable multi-vendor interoperable solutions connecting railroad and highway field equipment for HRI management.
🅂 Toll Administration to Toll Collection	• Dynamic Toll/Parking Fee Management • Probe Surveillance	General traffic information and toll collection status shared.	Regional standardization can enhance day to day operation and maintenance of systems. A regional standard will enhance the use of dynamic toll as a traffic management tool. A regional standard will also enhance the sharing of information among different toll agencies/companies for traffic management purposes.
Ⓢ National Interoperability		🅂 Regional Interoperability	△ Product Interoperability

4.3.3.2 Standards Requirements for Transit Management

The Architecture categorizes transit technologies into the following seven market packages:

1. *Transit Vehicle Tracking:* tracking transit vehicle locations in real time and using that information to help manage the system and inform passengers of service levels on a moment-by-moment basis.

2. *Fixed-Route Operations:* day-to-day monitoring, managing, and informing passengers about fixed-route transit services.
3. *Demand-Response Operations:* day-to-day monitoring and managing demand-responsive and flexible-route transit services, as well as providing passengers with service information and processing passenger requests for service.
4. *Passenger and Fare Management:* Using common fare media to pay for transit services, and monitoring of fare payment and passenger boarding patterns in real time.
5. *Transit Maintenance:* Monitoring critical systems on board the vehicle in real time and managing maintenance activities for the transit vehicle fleet.
6. *Transit Security:* Monitoring the safety and security of passengers both on board a transit vehicle as well as in other transit-related fixed locations, such as stops, stations, etc.
7. *Multi-modal Coordination:* Allowing transit vehicles to have priority at signalized intersections, HOV lanes, and freeway on-ramps.

In each of these seven areas, the architecture defines information flows between vehicles, the wayside/roadside, management centers and remote access (traveler information) devices.

Figure 4.3-7 shows the main subsystems in transit management as the transit management center and the transit vehicle. These, in turn, are connected to many other systems, including to the roadway (wayside) and other management systems. The figure show the full connectivity that might be envisioned if all of the seven market packages listed in Section 2 were implemented. Of course, depending on the choice of market packages and the details of a local system design, only a small subset of these interfaces may be relevant for a particular implementation. For example, for implementation of the passenger and fare management package, the primary interfaces are those connections between: 1) the electronic payment instrument and the vehicle; 2) the vehicle and the transit management center; and 3) the transit management center and a financial institution.

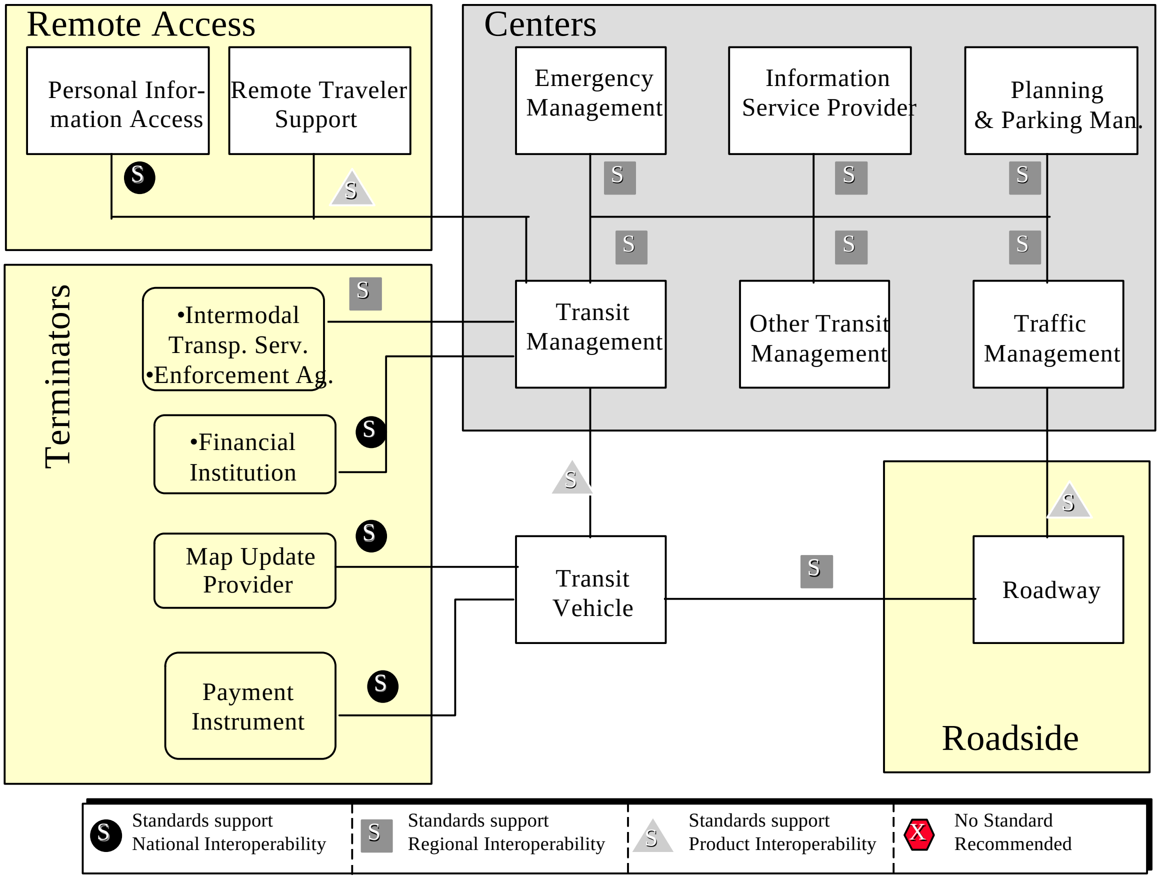


Figure 4.3-7: Connectivity and Standards Requirements for Transit Management

Table 4.3-3 describes each of the identified interfaces in more detail. The rationale for each interface standard highlights why and what kind of standards may be necessary, but does not necessarily indicate at this point how important or valuable these standards may be. The highest requirement for inter-operability are those interfaces where a device or vehicle may be used across a very broad geographic area or nation-wide. For transit management, such requirements may be placed on interfaces to remote information access devices, such as personal digital assistants (PDAs) or laptop computers that can access transit service information around the country. A similar national inter-operability requirement is placed on spatial data transfer between map and spatial data base providers and transit management. Other transit system interfaces are more regional in nature and may not require national interoperability.

Table 4.3-3: Transit Management Standards Requirements Overview

Interface	Supports Market Package	Description	Standardization Benefit
Transit Vehicle to △S Transit Management	• All Transit Services	Wide-area communication of vehicle status and operations monitoring actions between management and driver.	Product interoperability lowers cost and allows for more efficient training. Because transit vehicles rarely communicate across agencies, regional interoperability is not a requirement.
🅂 Roadside	• All Transit Services • Probe Surveillance (Traffic Management)	Alternative means of wide-area communication of vehicle status and operations management. Allows transit vehicle to communicate directly with traffic signal beacons to allow signal priority. Transit vehicles may also act as probes to roadside devices.	Consistent performance across regions allows vehicle migration across agencies and geographic areas.
Ⓢ Map Update Provider	• Transit Vehicle Tracking • Transit Security • Probe Surveillance (Traffic Management)	Provides reference signals for vehicle to determine geographic location to a desired level of accuracy.	Common interface allows universal means of determining vehicle location. Safety and security responses may be facilitated by common location referencing.
Ⓢ Payment Instrument	• Passenger and Fare Management	One- or two-way communications between fare payment instrument (e.g. electronic purse) and a reader on board the vehicle to receive and verify payment for services.	Common interface is a traveler convenience and improves operational efficiency.
Transit Mgmt to Ⓢ Personal Information Access	• Transit Vehicle Tracking • Fixed-Route Operations • Demand-Responsive Operations • Transit Security	One-way or two-way communication of vehicle location and expected travel time information to travelers. Access devices may also be connected with stop, station, or on-board security alarms and related devices.	Common interface is a traveler convenience and improves operational efficiency.
△S Remote Traveler Support	• Transit Vehicle Tracking • Fixed-Route Operations • Demand-Responsive Operations • Transit Security	One-way or two-way communication of vehicle location and expected travel time information to travelers. Access devices may also be connected with stop, station, or on-board security alarms and related devices.	Common interface is a traveler convenience and improves operational efficiency.
Ⓢ Map Update Provider	• All Transit Services	Base map and spatial data transfer provides common geographic and location referencing for vehicles, passengers, and other mobile and fixed entities.	Standard facilitates sharing of centrally maintained map data while allowing individual applications to select the GIS best suited to their needs.
🅂 Emergency Management	• Transit Security	Exchange of incident status information supporting early identification and rapid and appropriate coordinated response.	Standard facilitates inter-operability between diverse response agencies.
🅂 Traffic Management	• Multi-modal Coordination	Exchange of traffic information, transit service status, and traffic control data between traffic and transit management. Supports coordination in determining signal priority for transit vehicles.	Many agencies and jurisdictions may be integrated in institutionally complex metropolitan areas. Standard reduces development costs as existing autonomous systems are integrated and new systems are brought on-line.
🅂 Information Service Provider	• Transit Vehicle Tracking • Fixed-Route Operations • Demand-Responsive Operations	Enables communication of real-time transit information to the public through internal or third-party organization. Interface supports transfer of raw traffic data, processed measures of effectiveness, with associated data quality attributes.	Facilitates formation of firms to provide information, thus promoting competition, which may enhance service to travelers and revenue opportunities for transit management.
🅂 Other Transit Management	• Transit Vehicle Tracking • Fixed-Route Operations • Demand-Responsive Operations	Regional coordination between transit management subsystems enabling rapid response to special events or longer-term coordination of service.	Many agencies and jurisdictions may be integrated in institutionally complex metropolitan areas. Standard reduces development costs as existing autonomous systems are integrated and new systems are brought on-line.
🅂 Planning	• Multi-modal Coordination	Off-line transfer of daily traffic information to support on-going evaluation, planning, and research activities .	Provision of standard data facilitates development and application of standard planning support tools. Facilitates area-wide and comparative analyses.

Interface	Supports Market Package	Description	Standardization Benefit
Ⓢ Financial Institution	- Passenger and Fare Management	Off-line communication of passenger account information to a central clearinghouse to process fare payments and allocate fare revenues to appropriate agencies.	Standardization allows common interfaces, thus streamlining information processing and financial accounting.
S Traffic Management to Roadside	- Multi-modal Coordination - Probe Surveillance (Traffic Management)	Communication to provide appropriate traffic signal control and authorization for transit signal priority. Communication of transit vehicle locations and speeds as probe data to the traffic management center.	Standardization can enhance day to day operation and maintenance of systems.

Ⓢ National Interoperability 🅂 Regional Interoperability S Product Interoperability

Standards Development and Implementation
The interface specifications and message sets recommended in the national architecture can be used to advance existing or emerging efforts to develop standards. A number of groups have already begun work on standards for public transportation communications and electronic data exchange. Prominent among these is the ISO Working Group 8 and the European Committee for Standards (CEN) Working Group 3. ITS America's APTS Working Group on Map and Spatial Data Base Standards and other groups in North America are also promoting standards development. The national architecture can provide useful definitions of message sets and interface requirements. Broad participation in the standards development process will insure that the standards are of value to a large number of agencies so that the standards are widely adopted.

In public transit, particularly in the United States, standards development is a slow process. Therefore, it is likely that mature standards may not be available for 5-10 years. In the interim, some of the emerging standards (e.g. the CEN standards) may be appropriate for implementors in the US. The dilemma facing potential implementors is whether to purchase ITS components that may not comply with the standards or forego the benefits of ITS until standards are adopted. Arguments can be made on either side of this issue, and the answer for each transit agency will depend on their attitudes toward risk and the potential costs and benefits of the new technology.

At the same time, many progressive transit agencies have proposed open standards in their system specifications, and these specifications have effectively become *de facto* standards for the industry. This may be an alternate path to development of interface standards, and may shorten the time to a "consensus" standard by a considerable amount.

Through either process of development, the resulting consensus standards will be available to the transit management system developer for use in procurement of new systems and upgrade of existing systems. Adoption of these standards encourages inter-operability between systems and enables insertion of new technologies over time. For transit managers, this means that a larger number of vendors may supply products that can work with each other, and may be replaced without being locked in to proprietary systems. The open standards can also provide private firms with access to broader markets and encourage competition among suppliers. Ultimately, the economics of standards may reduce the cost of system design, procurement, operations and maintenance.

4.3.3.3 Standards Requirements for Traveler Information Systems

A key feature of the National Architecture is its clear distinction between transportation management and traveler information functions through definition of the Information Service Provider (ISP) subsystem. The interfaces between the ISP and potential multi-modal transportation information sources are defined and prioritized by the architecture to enable either private or public sector dissemination of traveler information via subscriber-based services or public access systems

The National Architecture does not mandate a particular approach to traveler information collection and dissemination within a region. Public sector development of a regional traveler information center, cooperative development of an networked complex of distributed public and private information centers, and provision of minimally formatted raw data to the private sector for processing and distribution are all supported by the architecture. Individual implementation decisions will be made based on regional policies and the local market for traveler information services.

However, the National Architecture does recommend standards for traveler information systems that are intended to enhance interoperability between major systems to facilitate information collection and dissemination and ultimately enhance the timeliness, quantity, and quality of information available to the traveler. Assessing the implications of the national architecture principally involves matching these standard interfaces to the local system.

Figure 4.3-8 focuses on the interfaces identified within the national architecture which facilitate development, operation, and maintenance of traveler information systems within a region. There is not a one to one correspondence between the interfaces illustrated in the figure and the number of standards that will ultimately be identified or developed. In general, many standards are required to fully define the multiple layers of message definitions and data transport requirements, and physical characteristics for each interface. Compounding this issue is the requirement for multiple application message sets required to support different ITS (and non-ITS) services over the same interface.

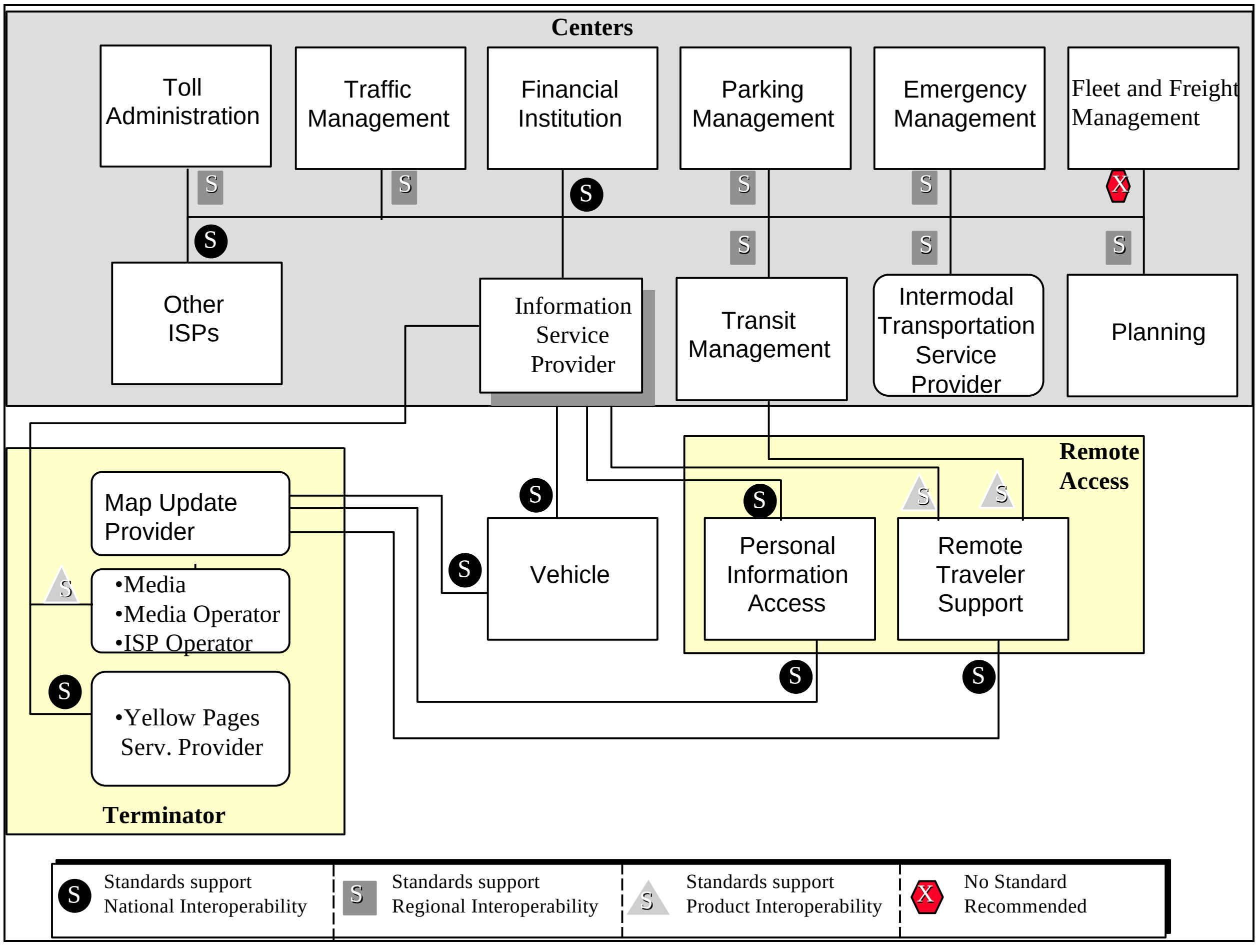


Figure 4.3-8: Traveler Information Interfaces

Additional definition for each of the identified standard interfaces is provided in table 4.3-4. Refer to the separate Standards Development Plan and Standards Requirements Plan for additional information.

Table 4.3-4: Traveler Information Standards Requirements Overview

Interface	Supports Market Package	Description	Standardization Benefit
ISP to Ⓢ Vehicle and Personal Information Access	• Broadcast Traveler Information • Interactive Traveler Information • Dynamic Route Guidance • ISP-Based Route Guidance • Integrated Transportation Mgmt/Route Guidance • Yellow Pages and Reservation • Dynamic Ridesharing	Provision of traveler information via wide area wireless communications. Both broadcast and interactive information services are supported .	Standard interface enables national (or international) markets, limits regional variation in in-vehicle radio equipment, and enables the user to benefit from mobile equipment anywhere in the nation.

Interface	Supports Market Package	Description	Standardization Benefit
△S Remote Traveler Support	• Broadcast Traveler Information • Interactive Traveler Information • Dynamic Route Guidance • ISP-Based Route Guidance • Integrated Transportation Mgmt/Route Guidance • Yellow Pages and Reservation • Dynamic Ridesharing	Allows access to information for "all modes and all roads" via kiosks or other traveler information access devices in public areas. Direct interface to Transit Management Subsystem reflects potential deployment of information kiosks, real-time schedule displays, imminent arrival signs, and other focused traveler information at the transit stop.	Standardization benefits day to day operation and maintenance of public traveler information devices.
Ⓢ Map Update Provider	• All services	Spatial data transfer standard enabling off-line sharing/update of map data that is the underpinning for many traveler information services.	Allows the ISP to utilize available map data while allowing individual applications within the region to select the GIS best suited to their needs. Prevents consumer from being tied to a single map provider.
Ⓢ Information Service Provider	• All Services	Information service providers in different regions may form agreements to exchange information so that long distance multi-modal travel information can be made available.	A standard traveler information exchange format allows ISPs to serve customer's needs even for trips outside the normal coverage area.
Ⓢ Financial Institution	• Interactive Traveler Information • ISP-Based Route Guidance • Integrated Transportation Mgmt/Route Guidance • Yellow Pages and Reservation	Supports electronic payments for user fees in exchange for traveler services performed by the ISP.	Leverages existing and emerging electronic funds transfer standards for use in ITS applications.
🅂 Toll Administration	• Interactive Traveler Information • ISP-Based Route Guidance • Integrated Transportation Mgmt/Route Guidance • Yellow Pages and Reservation	Enables current pricing information and other tollway status to be made available to the traveler.	Standard enables general access to toll road information.
🅂 Traffic Management	• Broadcast Traveler Information • Interactive Traveler Information • Dynamic Route Guidance • ISP-Based Route Guidance • Integrated Transportation Mgmt/Route Guidance	Principle source for real-time traffic information. Traffic information from other sources may be returned to the traffic management subsystem.	Facilitates entry and competition among private information providers enhancing service to travelers and revenue opportunities for traffic management subsystems.
🅂 Transit Management	• Broadcast Traveler Information • Interactive Traveler Information • Dynamic Route Guidance • ISP-Based Route Guidance • Integrated Transportation Mgmt/Route Guidance	Principle source for real-time transit information.	Facilitates entry and competition among private information providers enhancing service to travelers and revenue opportunities for transit management subsystems.
🅂 Parking Management	• Broadcast Traveler Information • Interactive Traveler Information • Dynamic Route Guidance • ISP-Based Route Guidance • Integrated Transportation Mgmt/Route Guidance	Current parking occupancy, pricing, and facility information made available.	Facilitates entry and competition among private information providers enhancing service to travelers.
🅂 Planning	• ITS Planning	Traffic and related information may be useful for planning purposes. Having a standardized interface facilitates better coordination.	Regional interoperability enhances the exchange and use of traffic information collected from different sources.

Interface	Supports Market Package	Description	Standardization Benefit
🅂 Intermodal Transportation Service Provider	• Broadcast Traveler Information • Interactive Traveler Information • Dynamic Route Guidance • ISP-Based Route Guidance • Integrated Transportation Mgmt/Route Guidance	Allows access to information for non-surface transportation modes so that true multi-modal information service is available to the traveler.	Facilitates ready access to intermodal information promoting competition among information providers and better information to the traveler.
X Fleet and Freight Management	• Fleet Administration	Provides specialized traveler information that is tailored for the unique requirements for the various vertical markets in the commercial fleet industry.	No standard is recommended since the interface may be customized to support the specific needs of commercial fleets, including: (1) height and weight restrictions on roadways, (2) weather related roadway conditions that affect commercial vehicles, (3) reduced speed limits for large-sized vehicles, (4) location and hours of inspection stations, and (5) locations of truck-specific services, such as diesel fuel, large-vehicle towing and repair, and truck rest stops. The interface must be designed to support communication of this and other information that is specific to commercial vehicles.
Map Update Provider to Ⓢ Vehicle, Remote Traveler Support, and Personal Information Access	• All services	Spatial data transfer standard enabling off-line sharing/update of map data that is the underpinning for many traveler information services.	Prevents consumer from being tied to a single map provider. As an alternative, multiple competing "standards" may co-exist in the market, each providing national coverage and varied features in vying for customers. Consumer products could support multiple interfaces.
Ⓢ National Interoperability		🅂 Regional Interoperability	△ Product Interoperability

4.3.3.4 Standards Requirements for Fleet and Freight Management Systems

The National Architecture preserves maximum choice for the motor carrier industry while recommending standards for key interfaces within and between the diverse public sector agencies that administer, regulate, and operate commercial fleets. In this area, the Commercial Vehicle Information Systems Network (CVISN) program provides an additional level of detailed definitions, operational concepts, and initiatives. Standard interfaces between the commercial fleet and the public sector facilitate and streamline the regulation of commercial fleets with mutual benefits to the public and private sector. In contrast, standards for interfaces that do not involve the public sector are left to industry and the market to develop. Figure 4.3-9 focuses on the interfaces identified by the National Architecture that directly support freight and fleet management. Table 4.3-5 describes the need for and benefits of interface standards.

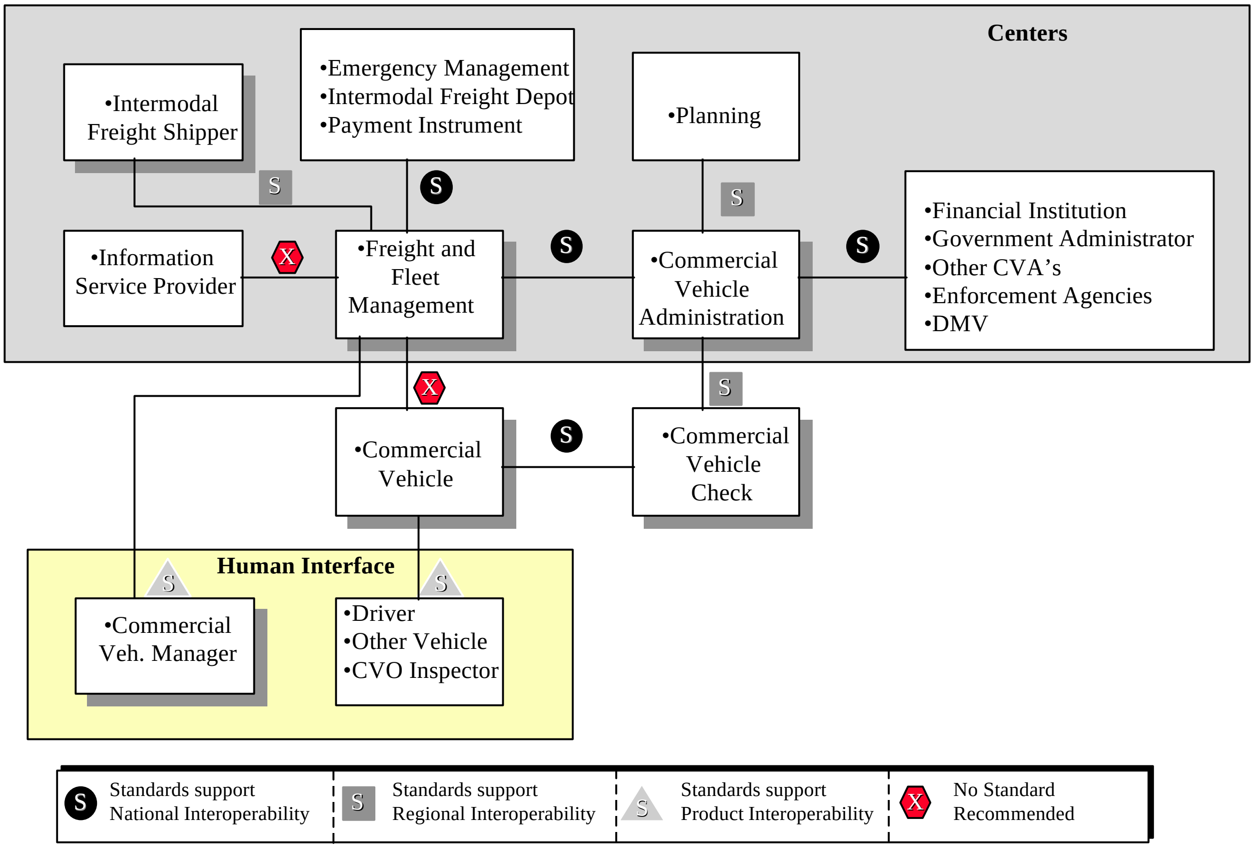


Figure 4.3-9: Freight and Fleet Management Standards Requirements

Table 4.3-5: Freight and Fleet Management Standards Requirements Overview

Interface	Supports Market Package	Description And Standardization Benefit
Commercial Vehicle to S Commercial vehicle Check	- Electronic Clearance - International Border Electronic Clearance - Weigh-in-Motion - Roadside CVO Safety - On-board CVO Safety	A standard interface is recommended between commercial vehicle transponders and roadside check points, to reduce or eliminate delays at inspection stations and to achieve national interoperability. Standards will be needed for several transponder functions, in support of the following ITS market packages: Electronic Clearance: The vehicle will transmit information related to: vehicle and driver licenses and permits, carrier operating authority, vehicle profile (including size and weight), commercial vehicle safety inspection, and cargo characteristics (such as HAZMAT). The roadside will send instructions to drivers (e.g., whether or not a stop is required) via on-board interfaces, and send a message to the vehicle identifying its position. Standards are needed to format these messages and determine their content. A particular issue will be deciding whether roadside sites should access permit and license information from centralized databases, or whether that information should be stored on the vehicle and transmitted to the roadside site. International Border Clearance: Standards are required to facilitate pre-clearance of cargo traveling to/from Mexico and to/from Canada via commercial vehicles. Standards are needed to support U.S. Customs and the Department of Agriculture in reducing or eliminating the need to inspect vehicles as they cross these international borders. This may entail transmitting an identification number, from which customs can access data on the particular shipment and determine whether the cargo has been pre-cleared. These standards should reflect progress already made through ENCOMPASS (a joint venture of AMR and CSX). In addition, standards should be developed to expedite inspections by state departments of agriculture at state borders. Dynamic Toll/Parking Fee Management Standards are required to support automatic toll collection from commercial vehicles. These standards should allow for the communication of vehicle size and weight to the toll collection agency to determine appropriate toll (see also toll collection interface in traffic management section). On-board CVO Safety: In contrast to Roadside CVO safety, which entails passive inspection from sensors mounted at roadside, on-board CVO safety entails diagnostic systems mounted on the vehicle. Through the transponder, information could be relayed on vehicle status to the roadside. Standards may be required in the future for formatting messages on safety related failures.
X Freight and Fleet Management	- Fleet Administration - Freight Administration - CVO Fleet Maintenance	No standard is recommended for this interface, which supports the market packages of fleet and freight administration and CVO fleet maintenance. However, as reporting systems shift from paper to electronic media, it will become necessary for carriers to institute systems that download additional regulatory information from their vehicles, to support fuel reporting, hours-of-service accounting, filing of daily inspection reports, and performing periodic maintenance inspections. Additional information may be transmitted to support a carriers' internal operations, including vehicle location, delivery instructions and shipment status.
S Driver	- Fleet Administration - Electronic Clearance - International Border Electronic Clearance - Weight-in-Motion - Roadside CVO Safety - On-board CVO Safety	Standardized human interfaces are recommended for vehicle operators, as well as CVO inspectors, to promote product interoperability. Standardization would make it easier for commercial vehicle operators to substitute and interchange products in the vehicle, and would simplify training and improve efficiency and safety for drivers
Commercial Vehicle Administration to S Commercial Vehicle Check	- Electronic Clearance - International Border Electronic Clearance - Roadside CVO Safety - On-board CVO Safety	A standardized interface is recommended to support regional interoperability. This will enable roadside sites to access data on vehicles and drivers from centralized databases, to verify and access credential information, and to share information on vehicle routing, cargo and driver.

Interface	Supports Market Package	Description And Standardization Benefit
S Other Commercial Vehicle Administration.	• All Market Packages	Standardized interfaces have already been developed for communicating information between agencies in different states in support of programs for single-state driver licensing and single-state vehicle registration (under the Commercial Vehicle Safety Act of 1986 and the International Registration Plan). Standards are also being developed for fuel tax reporting under the International Fuel Tax Agreement (IFTA). In most states, enforcement of vehicle and driver regulations (including safety inspections) is the responsibility of the police departments (principally, the state police or highway patrol) whereas the licensing and permitting responsibility lies in the motor vehicles department. National standards are recommended for this interface to support national interoperability. The primary function will be to enable police officers to access vehicle and driver records through mobile data terminals to ensure that the vehicle has proper credentials. The recommended interface if for landline communication from police department to state agency. However, at some future time, this interface would be supplanted if the information can be accessed directly from the commercial vehicle via its on-board transponder.
S Planning	• ITS Planning	A standardized interface is recommended for regional interoperability. Planning will need to access operational data to perform surveys of commercial vehicle operations (such as truck volume, weight and size studies) and to develop plans for serving freight transportation.
S Freight and Fleet Management	• CV Administrative Processes • HAZMAT Management	A standardized interface is needed between commercial carriers and commercial vehicle administrators (including departments of motor vehicles, intra-state commerce departments, highway patrol, and financial institutions), to expedite the permitting and licensing process, to simplify filing periodic reports and to simplify or eliminate terminal inspections. Pertinent information will include miles traveled by state (for fuel taxation purposes), vehicle and driver safety and maintenance records, and hours-of-service records for each driver. Motor vehicle departments can provide driver safety records and notices to fleet operators as part of pull-notice programs through this interface.
Freight and Fleet Management to S Intermodal Freight Shipper	• Freight Administration	Standards have already been developed by ANSI and the United Nations for transmission of shipment data between customers and carriers. Standards do not exist for communicating information on desired time and place of pickup and delivery, and for tracking shipments in transit. Standards are recommended to provide regional interoperability.
X Information Service Provider	• Fleet Administration	Standardized interfaces are not recommended between information service providers and freight/fleet management centers. Traveler information market packages must be customized to support the specific needs of commercial vehicles, including: (1) height and weight restrictions on roadways, (2) weather related roadway conditions that affect commercial vehicles, (3) reduced speed limits for large-sized vehicles, (4) location and hours of inspection stations, and (5) locations of truck-specific services, such as diesel fuel, large-vehicle towing and repair, and truck rest stops. The interface must be designed to support communication of this and other information that is specific to commercial vehicles. Refer to traveler information system section for information on the vehicle interface.

Interface	Supports Market Package	Description And Standardization Benefit
S Emergency Management	• HAZMAT Management • Emergency Response	A standardized interface is recommended between vehicles and emergency management centers and vehicles (see following section). In addition, a standardized interface is recommended between emergency management centers and freight and fleet management centers for national interoperability. The primary purpose will be to rapidly access information on cargo characteristics to assist in hazardous material cleanup. In addition, mayday messages from commercial vehicles may be relayed to emergency management centers via freight and fleet management centers. HAZMAT Management In the event of a hazardous materials incident, emergency management personnel may need to access information on the cargo manifest and information on clean-up procedures. This information may be accessible electronically via the on-board transponder. Standards are needed to format information that can be downloaded from these transponders to mobile terminals, which may be carried by emergency management personnel. Emergency Response: The transponder should conform to standards created for interface to emergency 911 systems. Specific to commercial vehicles, the mayday message should include information on the cargo carried and the vehicle profile to assist dispatchers in sending appropriate clean-up equipment and to assess the severity of the incident. Identifying information might also be transmitted to assist in apprehending criminals.
S Commercial Vehicle. Manager	• Fleet Administration • Freight Administration	Standardized human interfaces are recommended for commercial vehicle managers to promote product interoperability. Standardization would make it easier for commercial vehicle operators to substitute and interchange products and would simplify training and improve efficiency for dispatchers.

S National Interoperability S Regional Interoperability S Product Interoperability X No Interoperability Req

4.3.3.5 Standards Requirements for Emergency Management

Figure 4.3-10 identifies the types of standards recommended for developing regional interoperable emergency systems. For interoperability, communications between these centers should comply with a set of regional standards: Traffic Management, E-911, Information Service Provider, Media, and Emergency Management. The same applies to the communications between emergency vehicles and emergency management centers. For other types of vehicles or traveler information systems, a national standard should be established for emergency notifications or MAYDAY. This standard will ensure the receipt of these messages by the proper authority or agency throughout the entire country in a timely manner. The private sector might participate in situations in which the local emergency management agencies do not have sufficient resources to receive emergency notifications or are concerned with potential false-alarms. This is modeled as a private emergency management subsystem within the National Architecture. By charging a subscriber fee for the provision of this service, the private emergency management system can receive and screen these messages, provide assistance to vehicles in non-emergency cases, and forward these signals to the proper authority for emergency cases. In the latter case, the regional emergency agencies may want to develop a set of performance specifications to ensure that these emergency calls are received in a timely manner.

The National Architecture also supports situations in which the distressed vehicles inform the emergency management center through their respective fleet management centers. In this case, the emergency signals transmitted by these vehicles do not have to comply with the national standard. An exception is for incidents involving hazardous material; it would be highly beneficial if the content and nature of the spill were made available directly to the emergency management center or clean-up crew. Such a standard should be established for vehicles carrying hazardous material.

Table 4.3-6 describes each interface and the recommended type of standard.

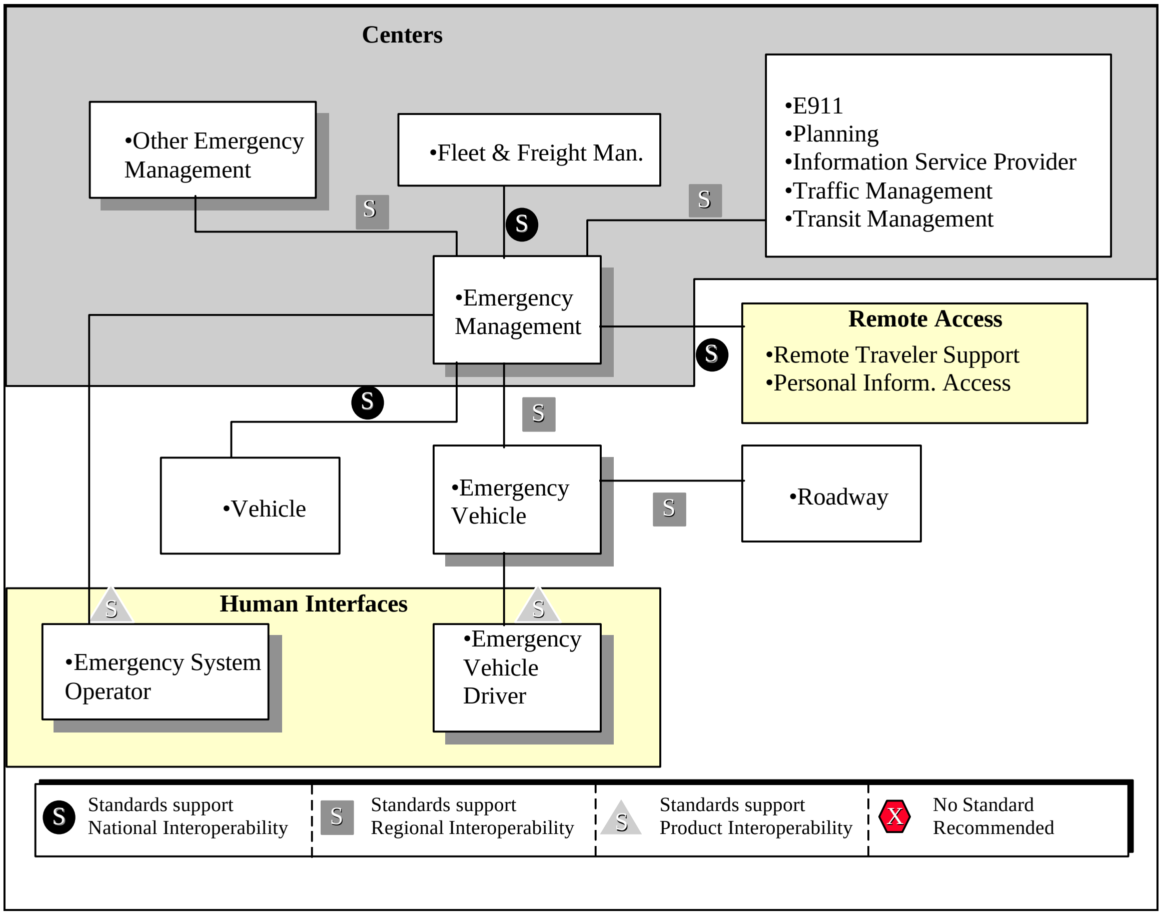


Figure 4.3-10 Emergency Management Standards Requirements

Table 4.3-6: Emergency Management Interfaces Overview

Interface	Supports Market Package	Description And Standardization Benefit
Emergency Vehicle to S Roadway	• Emergency Routing	A regional standard is recommended for the interface between the emergency vehicle and the roadside subsystem, primarily for signal preemption. A regional standard will facilitate the use of emergency vehicles across jurisdictional boundaries. Since emergency vehicles are rarely used over a large geographical scale, national standards are not recommended.
S Emergency Vehicle Driver	• Emergency Response	Standardized human interfaces are recommended to make it easier to substitute and interchange products in the vehicle and to simplify training and improve efficiency and safety for drivers.
Emergency Management to and from		

Interface	Supports Market Package	Description And Standardization Benefit
🅂 Emergency Vehicle	• Emergency Response • Emergency Routing	This standard is recommended for regional interoperability. Dispatch of and communication between emergency vehicles occurs frequently. As a minimum, the communication channel and frequency should be standardized. Regional, rather than national, interoperability is recommended because emergency vehicles rarely operate in a large geographical scale.
Ⓢ Vehicle	• Mayday Support	National standards are recommended because vehicles travel across the country. his may be a service in which the investment of the private sector can be leveraged. For example, AAA and other companies are already offering this service to subscribers. Such companies should have a role in developing the national standards.
Ⓢ Remote Access Systems	• Mayday Support	Standards similar to those for the interface between Emergency Management and Vehicle.
🅂 Other Emergency Management	• All Emergency Management Services	A regional standard is recommended so that emergency agencies can coordinate their response, especially during major emergencies, such as earthquakes. Currently the CAD systems of different emergency units do not communicate with each other due to lack of regional standards. Some emergency agencies are interested in creating standards for CAD systems.
Ⓢ Fleet and Freight Management	• HAZMAT Management	Because freight fleets operate nationwide, a national standard is recommended for this interface. In the event of a hazardous materials incident, emergency management personnel may need to access information on the cargo manifest and information on clean-up procedures. This information may be accessible electronically via the on-board transponder. Standards are needed to format information that can be downloaded from these transponders to mobile terminals, which may be carried by emergency management personnel.
🅂 E-911	• Emergency Response	Regional standards are recommended for this interface because E-911 calls may be forwarded from one agency to another in the region. In many parts of the country, the standard and procedure for 911 calls have already been established. If the E-911 function—automatically forwarding the caller's location-- is added to cellular calls, then this would be tremendous help to highway patrol, since cellular calls have become one of the fastest and most efficient way of notifying incidents.
🅂 Planning	• ITS Planning	Regional standards are recommended so that planners can access data from many source.
🅂 Information Service Provider Traffic Management Transit Management	• All Emergency Market Packages • HAZMAT Management • Incident Management • Transit Security	Regional standards are recommended for the interface between emergency management and information service provider, traffic management, and transit management, to facilitate coordination of responses to emergencies.
△S Emergency System Operator	• All Emergency Market Packages • Incident Management	Product standards are recommended for these interfaces to facilitate substitution and interchange of products. This could lower costs, simplify training, and improve efficiency for operators.

Ⓢ National Interoperability 🅂 Regional Interoperability △S Product Interoperability

4.3.3.6 Standards Requirements for Vehicle Safety Systems and Automation

The National Architecture preserves maximum choice for vehicle manufacturers, OEMs, after-market product providers, vehicle owners, and drivers. While emphasizing non-interference, the National Architecture makes specific national standard recommendations designed to maximize public safety. These standards help manufacturers by consolidating markets, thus allowing economies of scale, the benefits of which may be passed on to consumers. Vehicle safety systems and automation involve the following types of interfaces:

1. Interfaces between the vehicle and the roadway.
2. Interfaces between and/or among vehicles on the roadway
3. Interfaces between the roadway and transportation management centers
4. Interfaces between the vehicle and the driver within each vehicle

There is general consensus that standards are necessary for each of the external interfaces to the vehicle, including the driver interface. However, the interactions between the various safety systems and the different mechanical, electrical and computer systems within the vehicle will likely remain proprietary.

Standards for the interface between the Vehicle Monitoring System and external infrastructure management agencies are required. For example, it is very likely that in an Automated Highway System (AHS) a malfunctioning vehicle is dangerous not only to itself but also to others. Thus it is important that an AHS have access to the results produced by a Vehicle Safety Monitoring System.

Intersection Collision Avoidance, especially the provision of timely warnings, requires infrastructure support. The information broadcast by the infrastructure must be in a format an approaching vehicle can understand and respond to, if necessary, in a timely manner, i.e. execute the necessary control actions. This interface between the vehicle and the intersection collision avoidance infrastructure must be standardized.

In addition to the interoperability standards, performance specifications may also be desirable for the AVSS market packages. There are numerous on-going ITS projects in this area (Refer to *Intelligent Transportation Systems (ITS) Projects*, January 1995, U.S. Department of Transportation, pp 233-240).

For safe and efficient operation an AHS will require performance standards on the control and sensing capabilities and interoperability standards for communication of all vehicles using the AHS. AHS communications systems are expected to support three types of links, including vehicle to vehicle, vehicle to infrastructure, and infrastructure to vehicle (Refer to*Assessment of Enabling Technologies for Automated Highway Systems-Draft Report for Task WBS B2*, Revision 1, July 1995, National Automated Highway Systems Consortium).

For the safe operation of an AHS involving "hands-off" driving, it is necessary that the driver be able to take control of the vehicle when expected to by the infrastructure. If the driver is unable to do so then it is important that the infrastructure be informed of the same. Thus standards are required in the reliability, functionality and the interface between this market package and the infrastructure.

Longitudinal and lateral safety warning systems represents a service provided by the vehicle to its driver. Its functionality does not involve other vehicles on the road, except in a very indirect manner. The functionality of this package can be achieved by line-of-sight sensing. Consequently, no infrastructure support is required. The benefits of standards would be economies of scale, avoiding mutual interference of sensors, settling spectrum for sensors, and providing common Human-Machine Interface (HMI) characteristics to minimize problems for drivers.

Driver visibility improvement systems represents a service provided by the vehicle to its driver. Its functionality does not involve other vehicles on the road, except in a very indirect manner. The functionality of this package is to be achieved by vision sensors mounted on the vehicle. The reliability of a vision sensor in detecting traffic signs and other infrastructure indications can be greatly influenced by the choice of color and layout of the sign. Adoption of suitable standards on traffic signs can greatly improve the efficacy of machine vision. However, current standards are obviously adequate for human drivers. Since this package is not intended to substitute for the visual capabilities of the driver, but rather to assist them, the adoption of standards for effective machine vision is not a pressing concern.

Advanced vehicle longitudinal control systems can be assessed in two contexts. In one context it is a service provided by the vehicle to its driver. Its functionality normally does not involve other vehicles on the road, except in an indirect manner. Thus standards are encouraged but not required except for issues called out above (sensors, spectrum, HMI). However, there may be exceptions. One example is the use of cooperative reflectors at the rear end of vehicle for longitudinal warning or control. Standards are required in this case for interoperability.

The second context arises from its role as a crucial component of AHS. Vehicles in an AHS require Advanced Vehicle Longitudinal Control (AVLoC). Moreover in an AHS the reliability and functionality of the AVLoC determines the safety and efficiency of the entire AHS. Thus for participation in AHS the reliability and functionality of AVLoC must be standardized.

The technological development path for Advanced Vehicle Lateral Control (AVLaC) systems suggests that lateral control systems will require sensing assistance from the infrastructure to achieve high reliability in the near and medium term. This sensing assistance may be provided by magnetic markers, tapes and various other devices placed on the road. Thus standardization of the operational characteristics of these devices is required for them to be usable by vehicle lateral control systems. This package can be assessed in two contexts. In one context it is a service provided by the vehicle to its driver. Its functionality does not involve other vehicles on the road, except in an indirect manner. Thus standards are encouraged but not required. Its second context is its role as a crucial component of AHS. Vehicle in an AHS require AVLaC. Moreover in an AHS the reliability and functionality of the AVLaC determines the safety and efficiency of the entire AHS. Thus for participation in AHS the reliability and functionality of AVLaC must be standardized.

Standards for these and related interfaces are described in Table 4.3-7.

Table 4.3-7: Advanced Vehicle Safety Systems Standards Requirements Overview

Interface	Market Package	Description	Standardization Benefit
Ⓢ Vehicle to Roadway	• Intersection Collision Avoidance • Intersection Safety Warning • Automated Highway System • Vehicle Longitudinal Control • Vehicle Lateral Control	Vehicle is able to receive roadway geometry information from the roadway infrastructure and information about obstacles/vehicles it is blind to. An example is the communication of stationary obstacles via reflective markings. In AHS, the vehicle is able to receive driving parameters, path planning information from the automated highway and the automated highway is able to receive driver condition, vehicle condition and emergency information from the vehicle.	National Interoperability . vehicle owners are not required to purchase many different communication interfaces to realize enhanced safety. Safe and efficient operation of Automated Highway System
Ⓢ Vehicle to Vehicle	• Intersection Collision Avoidance • Automated Highway System	Supports communications required by control protocols for cooperation between vehicles required for the safety and efficiency of the AHS. The use of reflective markings at the rear end of vehicle for longitudinal control is an example of early application of vehicle to vehicle “communication”.	Safe and efficient operation of cooperative driving operations, and Automated Highway System
🅂 TMC (AHS) to TMC	• Automated Highway System	Coordination of inflow and outflow to and from the AHS.	Regional inter-operability, inter-jurisdictional co-ordination, and avoidance of queuing and delays.
🅂 TMC (AHS) to Emergency Management	• Automated Highway System	Exchange incident information for rapid and coordinated emergency response.	Enhanced Safety and emergency response ability. Regional inter-operability, Inter-jurisdictional coordination.
🅂 TMC (AHS) to Emissions Management	• Automated Highway System	Regional coordination between emissions management and AHMC subsystems enabling rapid response to detected hot spots	Standard interface may be replicated in numerous non-attainment regions pooling knowledge and saving development costs
🅂 TMC (AHS) to ISP	• Automated Highway System	Initially enables sharing of real-time traffic information. Interface supports transfer of raw traffic data, processed MOEs, with associated data quality attributes. Advanced service shares OD pairs enabling system optimal strategies	Facilitates entry and competition amongst private information providers enhancing service to travelers and revenue opportunities for AHS.
Ⓢ Vehicle to Driver	• All AVSS Market Packages	Provide vehicle operational status and dynamic driving environment information, determine the format for driver intervention in AHS operation.	Facilitate vehicle driver inter-operability i.e., drivers will not have difficulty in driving different vehicles

Ⓢ National Interoperability 🅂 Regional Interoperability △ Product Interoperability

4.3.4 Specifying the Regional Configuration

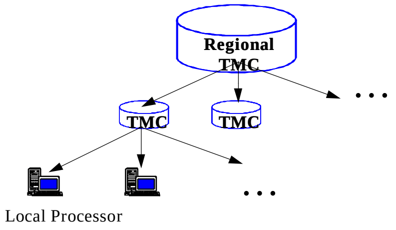
Several regional ITS architectures have been defined and presented in the ITS literature in the last few years; most as part of the Early Deployment Plan process or to support some of the larger operational tests. Invariably, these studies trade-off and select between centralized, distributed, and various hybrid forms of these two basic architecture configurations.

The National Architecture defines a series of peer-to-peer interfaces between center subsystems which support the sharing of both information and control. The definitions emphasize the application messages which are unique to ITS and presume that existing and emerging industry standard physical interfaces and lower-level protocols will be adopted for ITS. By selecting and adapting these basic interface definitions, either centralized, distributed, or hybrid architecture configurations may be derived from the National Architecture definition.

This section discusses the range of configurations that are supported by the National Architecture and may be implemented in a particular region. To illustrate the point, this section highlights the various regional traffic management configurations that are compatible with the National Architecture. The National Architecture takes the same flexible approach for each of the other stakeholder areas (i.e., transit management, commercial vehicle administration, emergency management, traveler information) with the same resulting configuration options in each area.

The National Architecture supports various approaches for coordinating traffic management systems in a given region. The interface definition that is central to this flexibility is the peer-to-peer interface between traffic management subsystems. (Reference the Traffic Management Subsystem to “Other TMS” interface in the Physical Architecture for more information.) The data flows defined for this interface enable the sharing of both control requests and information. The control requests support a range of distributed control strategies from strict hierarchies to more general network control configurations. The information exchanges enable cooperative control strategies which preserve each systems decision making autonomy but allow these decisions to be made with real-time knowledge of the status of neighboring jurisdictions. The information sharing also enables a variety of data replication and distribution strategies. Tables 4.3-8 and -9 summarize various approaches that enable various levels of traffic management coordination; each approach is supported by the National Architecture.

Table 4.3-8: Control Strategies Consistent with the National Architecture

Options	Description
Hierarchical	 ***Arrows represent the direction of control orders or commands***. *For example, a regional TMC controls a number*

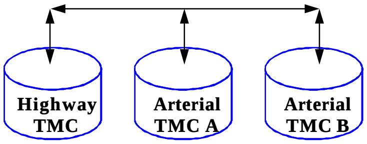
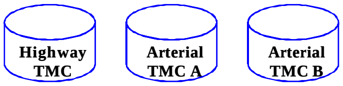
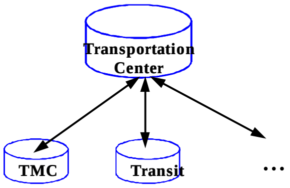
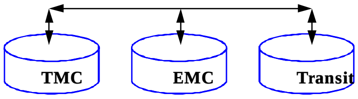
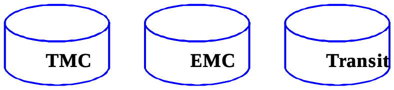
	of district TMCs or different types of TMCs, which in turn control local processors
Distributed	 *TMCs can make control requests to each other, perhaps under agreed upon circumstances and conditions.*
Isolated	 *TMCs cannot exert control on each other.*

Table 4.3-9: Database Distributions Consistent with the National Architecture

Options	**Description**
Centralized	 ***Arrows represent allowable data flows**. There is a centralized database repository that each TMC or agency has access to.*
Distributed	 *Database of each TMC or agency services remote requests from others.*
Isolated	 *Databases of each TMC or agency are not connected*

Different control and data distribution strategies can be combined to form hybrid systems, according to the types of traffic management functions and needs of local jurisdictions. For example, neighboring jurisdictions may want to form a centralized database which status's incidents at a regional level, but allow only isolated control for dispatch at each jurisdiction. The same jurisdictions may decide to work closely on signal coordination, form a centralized database for traffic surveillance, and use a distributed control system to operate signals.

4.4 Developing a Strategic Deployment Plan

Once the vision is established, ITS solutions are identified that address the region's transportation problems, and a regional architecture is established as an integrative framework for future implementations, specific ITS projects can be identified and planned. The Strategic Deployment Plan includes all information necessary to identify and support the planned ITS projects for the region.

The purpose of the Strategic Deployment Plan is to guide the implementation of ITS projects on a geographic scale appropriate to the needs and objectives of the system. The Plan will be used as a primary source in the on-going consensus-building associated with ITS. This process involves the identification of early deployments, development of an Action Plan, and identification of agency responsibilities. The Action Plan should identify the appropriate technologies, operational procedures, and appropriate materials and documentation to facilitate the most efficient introduction of, and the necessary funding for, the selected ITS deployments. For example, the Action Plan should consider and recommend the upgrade and enhancement of the Transportation Management Center, and the upgrade and enhancement of the traveler information including transit information and coordination with the transit management systems.

To accomplish this step, state and local agencies should have detailed understanding of these aspects regarding the region (*Interim ITS Planning Handbook*, 1996):

1. Transportation system problems, opportunities, and objectives
2. Institutional issues
3. Needed user services and market packages
4. System functional requirements by subsystem and technology area
5. System architecture requirements
6. Technology options
7. Implementation and operational strategies
8. Funding issues
9. System implementation or operations plan

Information from various analyses is used to develop the Strategic Deployment Plan. Section 2 of this Implementation Strategy showed the technology and standards requirements of the market packages, and identified early market packages for early deployment consideration. Section 3 discussed institutional issues and their implications for implementation; identified the producers, operators, and consumers of the system components; and summarized potential funding sources.

All of these are critical elements for developing the Strategic Deployment Plan. Table 4.4-1 provides a complete list of Architecture references where useful information can be found.

Table 4.4-1: Architecture Products for Developing Strategic Deployment Plan

Information Requirements for Strategic Deployment Plan	ITS Architecture Products
1. Transportation system problems, opportunities, and objectives	V, IS Sect. 1
2. Institutional issues	IS Sect. 3
3. Needed user services and market packages	IS Sect. 2, 4.2
4. System functional requirements by subsystem and technology area	IS Sect. 2 and PA.
5. System architecture requirements	IS Sect. 2,4.3, and SDP
6. Technology options	IS Sect. 2 and PA
7. Implementation and operational strategies	IS 3
8. Funding issues	IS Sect. 3
9. System implementation or operations plan	IS Sect. 3 and 4.4
Notation: V - Vision, IS - Implementation Strategy, PA - Physical Architecture, SDP - Standards Development Plan	

As an initial step, a strategic deployment plan may benefit from establishing two types of inter-agency agreements: i) policy, and ii) operation. Under the policy component, strategic direction for the region is set with regard to integrated transportation systems and services. In the operational component, detailed operational concepts are developed to establish an integrated operational plan, with unified methods for transportation management.

(i) Inter-agency agreement: policy

ITS deployment often requires the creation of a multi-jurisdictional arrangement and the formulation of policy on jurisdictional boundaries, responsibilities, and accountabilities. Policy decisions

- Identify needs: Identify local needs in light of existing as well as forecast traffic and transportation problems. This should be done in coordination with agencies responsible for short- and long-term planning and implementation.
- Define goals: Determine the goals to be achieved by integrating transportation management functions region-wide. Identify services that are desired by the region, and the degree of cooperation needed to provide these services.
- Establish a coalition platform: Establish a regional ITS forum to facilitate metropolitan planning and deployment of ITS. Forums must represent the largest possible cross-section of public and private entities and stakeholders. Develop fair and equitable, and perhaps standardized procedures for negotiating and granting franchises for private ITS developers and operators, including information service providers (ISP) and telecommunications companies who are interested in participating in offering ITS services.
- Foster private-public Partnerships: Establish guidelines and policies to promote the creation of public-private partnerships
- Define role and responsibility: Define jurisdictional boundaries, responsibilities, and accountabilities with regard to the deployment and operation of ITS components.

- Resolve technical choices: Develop local, ITS-compatible operating strategies leading to selection of standards and protocols; identify needed research, and support the development and demonstration of ITS technologies in the region.
- Incorporate evaluation feedback: Form an evaluation team to assess the successes and the degree of effectiveness of the above strategies and recommend remedial actions.

(ii) Inter-agency agreement: operations

Jurisdictions need to consider institutional mechanisms for making operational decisions. For example, design and development of traffic management centers (TMC's) requires determining where planning recommendations should originate, who sets the design criteria, what constraints there are, who is responsible for the decision making, how binding are their decisions, who is responsible for implementation and operation, and how the center would be funded.

Successful implementation of integrated transportation management systems may require that, among other factors, the following implementation tasks be considered, agreed upon, and implemented.

- Establish criteria for choosing market packages: These criteria must satisfy local needs while ensuring regional compatibility.
- Define authority: Define clearly the division of operational authority, responsibilities, and principles of traffic control among agencies.
- Define and regulate rights-of-access: Who gets access to what? How many people would be granted access, how much access, for what purposes, in which form, for how long, and at what price? This includes access to and control of staff and equipment at local and integrated TMC's, and databases held by public agencies, franchises, high technology developers, system developers, private service providers, academic researchers, and others
- Delimit data and information sharing: Define what data are collected, how they are collected, where they are stored, and how they are shared.
- Establish standards: Set uniform specifications for field construction and design of roadway sensors and controllers. Set interface standards for communications between TMC, other centers, and field equipment. Decide which local/regional interoperability standards would be adopted, taking into consideration equipment already in use for automatic vehicle identification (AVI), Electronic toll and traffic management (ETTM), and specialized mobile radio (SMR) communication.
- Define communication spectrum: Define RF spectrum allocation and use compatible with the national architecture for regional and national interoperability
- Define application-level interfaces: Agree on a specific integrated implementation of a Database Management System for sharing data and application-development experience in the region. Address client-server paradigms, shared software development, and applications programming interface (API) issues.

- Standardize information dissemination format: Adopt a uniform highway advisory radio (HAR) and changeable message sign (CMS) format for the region to guarantee dissemination of consistent information to the motorists.
- Devise incident response strategies: event notification procedures, chain of command, and dispatch. This includes division of responsibilities, inter-jurisdictional procedures, collective-cooperative procedures to be used for on-site activities, and on-site communications protocols.
- Integrate surface street and freeway ramp control: Formulate ramp metering policies and control plans. Devise surface street to surface street, freeway to freeway, and surface street to freeway entrance ramp signal coordination and control plans
- Incorporate evaluation feedback: Form a technical evaluation team to identify emerging technical problems and propose suitable solutions.

These two types of agreements create a focus for the consensus building and coalition forming process. Detailed considerations and guidance of developing the Strategic Deployment Plan can be found in the *Interim ITS Planning Handbook (FHWA, 1996).*

4.5 Implementing the System

Once the Strategic Deployment Plan is in place and the identified ITS improvements are programmed into the appropriate Transportation Plans, the deployment process progresses into implementation as the planned systems are procured, designed, built, and accepted.

System procurement may take several forms, depending on the staff capabilities, bidding processes, time constraints, and operations and maintenance capabilities of the agencies involved. The entire process can be contracted out to a consultant, who is responsible for all work associated with the system development, including design, contracting, and system integration. Once the system is built, it is turned over to the agency to operate and maintain. At the other extreme, the entire design and integration process can be performed in-house, with subcontractors engaged only to build individual components. A middle ground is to hire a systems manager, who manages the system development process, with the implementation of individual components awarded through separate contracts to different contractors. The systems manager is responsible for maintaining interoperability between subsystems. See the *ITS Planning Handbook* for details.

Regardless of how the procurement is organized, the development of the procurement plan involves the following steps. The first is the identification of funding sources. Successful implementation will largely depend upon the availability of funds to cover the costs of ITS systems. Traditional funding sources that are available for these systems include: Federal-aid National Highway System (NHS) funds, Surface Transportation Program (STP) funds, Congestion Mitigation and Air Quality Improvement (CMAQ) sources, ITS Act funds, Federal Transit Funds, and state and local funds. The public portions of the ITS infrastructure can also be funded by state and local taxes, development fees, privatization projects, or sale of right-of-way for telecommunications networks. The private components of ITS, such as in-vehicle devices, routing services, and management systems for commercial vehicle operators, will be funded by the users.

The second step is the development of clearly defined performance and system specifications for the RFP or bidding process. Section 2 provided information on the architecture and subsystem connectivity. The *Logical Architecture* and *Physical Architecture* documents provide detailed functional and interface specifications that may provide a starting point for development of these system specifications. The National Architecture has been developed to support the greatest possible range of design options and technology choices. In the following subsections, we highlight the design options supported by the national ITS architecture for each major stakeholder area.

4.5.1 Traffic Management Design Options

The architecture supports the widest possible range of ATMS designs while preserving national interoperability through identified standards. This approach frees the implementor to select the best design to meet local needs. Table 4.5-1 illustrates the major design options for each Traffic Management Market Package.

Table 4.5-1: Major Traffic Management Design Options

Market Package	**Design Options Consistent with the National Architecture**
Network Surveillance	• Approaches: fixed instrumentation • Types of data collected: occupancy, speed, volume, density, travel time, images • Automation: fully automatic, require operator interpretation. • Intelligence: field processors filter raw data, raw data transmitted to TMC • Technologies: loop, CCTV, Machine Vision, acoustic and radar sensors; database management; data fusion. • Communication media: wireline--fiber-optics, coaxial cable, leased phone line; wireless-- microwave, • cell-based digital • Coordination: sharing surveillance data with neighboring TMCs versus not sharing.
Probe Surveillance	• Approaches: mobile instrumentation • Types of data collected: voice, digital--travel time, speed, road conditions • Automation: fully automatic, activation by drivers or operators • Intelligence: processors in probe to filter raw data, all raw data transmitted to TMC • Technologies: GPS at probe, other vehicle positioning systems; aerial surveillance; roadside beacons • Frequency of communication: time-based, location-based, incident-based, on request; communications media: analog cellular, cell-based digital, dedicated short range (beacon-tag) • Data transmitted to: TMC, independent service providers. • Participation as probes: voluntary, compulsory, for-hire, contract.
Surface Street Control	• Approaches: isolated versus coordinated intersection control within a jurisdiction; pretimed plans versus real-time traffic adaptive plans • Types of data used: occupancy, speed, travel time, video image; instrumentation--number of detectors per link • Automation: fully traffic responsive, operators select timing plans • Intelligence of processors: centralized, distributed (timing plans derived locally versus centrally) • Technologies: algorithmic--adaptive versus non-adaptive • Communication media: fiber-optics, coaxial cable, leased phone line. • Communication between TMC and local controllers: timing plans, travel time, queue length;

Market Package	**Design Options Consistent with the National Architecture**
Freeway Control	• Approaches: isolated versus coordinated ramp metering within a jurisdiction; pretimed plans versus real-time adaptive strategies for density control and incident management • Types of data used: mainline occupancy, speed, travel time, imaging, density, ramp occupancy; instrumentation--number of detectors per ramp • Automation: fully traffic and queue length responsive, operators in-the-loop incident management. • Intelligence of processors: centralized, distributed (timing plans derived locally versus centrally) • Technologies: detectors--loop, CCTV, Machine Vision; algorithmic--adaptive versus non-adaptive • Communication media: fiber-optics, coaxial cable, leased phone line. • Communication between TMC and local controllers: timing plans, travel time, queue length;
Regional Traffic Control	• Coordination approach: deriving control plans --hierarchical, centralized, distributed with common cycle lengths; sharing surveillance information: centralized databases, distributed databases • Types of data used: occupancy, speed, travel time, video image; instrumentation--number of detectors per link; inter-jurisdictional surveillance information • Automation: fully traffic responsive, operators select timing plans or initiate response plan • Intelligence of processors: centralized, distributed (timing plans derived locally versus centrally) • Technologies: detectors--loop, CCTV, Machine Vision; algorithmic--adaptive versus non-adaptive; database management • Communication media: fiber-optics, coaxial cable, leased phone line. • Coordination: control plans--hierarchical, centralized, distributed with common cycle lengths; sharing surveillance information: centralized databases, distributed databases
HOV and Reversible lane Management	• Approaches: Time of day versus traffic responsive HOV operations • Types of data used: time of day, traffic volume • Automation: fully automatic enforcement, manually invoked operations • Intelligence of processors: centralized, distributed (ramp meter plans for HOV on-ramps derived locally versus centrally) • Technologies: detectors--loop, CCTV, Machine Vision; algorithmic--adaptive versus non-adaptive; • Communication media with TMC: wireline--fiber-optics, coaxial cable, leased phone line; wireless--cellular phone, RF, cell-based digital
Incident Management System (Design Options for Incident Detection)	• Approaches: manual--operators reviewing CCTV; automatic--incident detection algorithms via using loop detector data or via VIP • Types of data received: CCTV footage, surveillance data from ATMS1 • Automation: fully automatic, manual initiation and confirmation • Intelligence of processors: centralized, distributed (incident pattern processed locally versus centrally) • Technologies: incident detection based on VIP, loop information • Communication media: wireline for surveillance data (see Surveillance) • Coordination: incident data may be shared through CAD with emergency management susbsystem; between TMC and signal control market packages to initiate response signal plans; between TMC and the incident dispatch market package to coordinate dispatch.
Incident Management System (Design Options for Incident Management)	• Approaches: manual notification--receiving cellular 911 calls, via FSPs, and other patrol field units; receiving automatic MAYDAY from troubled vehicles; manual dispatch with Computer Aided Dispatch (CAD) database shared among emergency agencies, automated dispatch based on AVL technologies • Types of information used: incident location, severity (hazardous material or not) and its real-time status, locations of response units • Automation: automatic dispatch via AVL application on response units, manual allocation of response units to incident • Intelligence: amount of information (such as CAD information) available to response units (e.g., mobile data units), dispatch from the field command versus from a central dispatch center • Technologies: database management--centralized and common CAD versus distributed CAD's (one for each agency); AVL on response units • Communication: voice versus digital data communication between response units and dispatch center; • Coordination: different levels of data flows and database management between TMC, Emergency Management subsystem, field units, and freeway and arterical control market packages to create seamless and coordinated response plans

Market Package	**Design Options Consistent with the National Architecture**
Traffic Information Dissemination	• Approaches: Traffic information disseminated directly from TMC, or via the media. • Data used: CMS or HAR messages, or media messages • Automation: control and invoke of CMS and HAR messages directly from TMC via modem in real-time, or manually invoke message at the field units • Intelligence: messages downloaded from TMC, versus setting up of messages by field personnel • Technologies: (not much variation) • Communication media: wireline versus wireless
Traffic Network Performance Evaluation	• Approaches: on-line versus off-line performance evaluation; historical data assessment, real-time assessment, and forecast • Types of data used/produced: traffic data, environmental data, travel demand data, route plans from ISPs • Degree of automation: generate performance reports on a regular base automatically; generate evaluation reports manually under request • Use of technologies: database management, traffic and environment modeling • Communication: wireline and wireless media to handle large volume of data coming in especially for real-time on-line processing • Coordination: varies according to use of evaluation results and time-scale of feedback, could be linked to surveillance, traffic control, and incident management market packages for real-time control adjustment or longer-term planning purposes for traffic demand management.
Regional Traffic Control	• Approaches: real-time simultaneous derivation of route plans and signal timing plans; off-line coupling for conducting planning studies such as improving signal timing plans. • Types of data used/produced: traffic data, travel demand data, route plans from ISPs • Degree of automation: fully automatic versus frequent manual intervention to correct and verify results • Use of technologies: levels of model computational efficiency • Communication: wireline and wireless media to handle large volume of data coming in especially for real-time on-line processing. • Coordination or subsystem connectivity: traffic control and route plans from ISPs should be linked and processed together.
Dynamic Toll / Parking Fee Management	• Approaches: electronically collect tolls, and detect and process violators; combined with traffic data to implement demand management strategies either on-line or off-line • Types of data used/produced: vehicle tag information, toll information, traffic data • Degree of automation: fully automatic in the whole process, manually determining toll strategies based on off-line traffic data; manually detect and process violators • Distribution of intelligence or processing capabilities: capabilities of the processors located at the field • Use of technologies: communications---short-range communications, RF, cell-based digital; database management • Communication: wireless (short-range, RF) between vehicle and tag reader, wireline between tag reader and financial institution • Coordination or subsystem connectivity: levels of coordination may include--with ATMS1, ATMS2 and ATMS10 to set up demand management strategies, with financial institution to verify and clear financial transactions.
Emissions and Environmental Hazards Sensing	• Approaches: manually or electronically sense emissions and environmental hazards; may include detection of emission violations; combined with traffic data to implement emission management strategies • Types of data used/produced: human warnings, emission levels, environmental hazards such as fog, and icy road conditions • Degree of automation: fully automatic in the whole process, manually determining the levels of hazards by field units • Distribution of intelligence or processing capabilities: capabilities of field processors to filter sensor measurements • Use of technologies: sophistication of environmental sensors • Communication: wireless or wireline between sensors and TMC • Coordination or subsystem connectivity: coordination with ATMS9 to disseminate information to travelers, and with ATMS10 to set up emission management strategies
Virtual TMC and Smart Probe	• Approaches: probes equipped with a variety of technologies for road surface sensing.

Market Package	**Design Options Consistent with the National Architecture**
Standard Railroad Grade Crossing	• Approaches: Isolated vs. coordinated with adjacent intersections. Interconnection vs. Preemption connectivity with adjacent intersections. Constant warning time vs. Minimum warning time systems. • Data Generated: Closure times and durations; health status; local highway traffic surveillance data. • Automation: Fully automatic, train responsive operation. • Intelligence: Interpretation of raw data may be locally performed by controller or transmitted back for processing at central facility. • Technologies: Traditional crossing signals and gates may be augmented with traffic control devices identified in other market packages (e.g., Traffic signals, HAR, VMS). In most advanced applications, beacons may provide HRI information directly to the vehicle for display to driver or for processing by automated vehicle control systems. • Communication: Relatively low data rates supported by many wireline/wireless options. • Coordination: Shared health status between traffic operations and rail operations.
Advanced Railroad Grade Crossing	Includes design options identified above for Standard Speed Market Package as well as: • Approaches: Detection of entrapped vs. Immobile vehicles or other obstacles • Data Generated: Obstruction alerts with supporting data for verification. • Automation: Automatic with various degrees of person-in-the-loop for verification and response initiation. • Intelligence: Interpretation of raw intersection surveillance data and images may be performed in the field or centrally. • Technologies: Various sensor technologies and image processing algorithms may enable entrapped/immobile vehicle detection • Coordination: Obstruction alerts may be communicated directly to railroad wayside equipment and/or rail operations center.
Railroad Operations Coordination	• Approaches: Projected HRI closure times may be passed directly or developed from raw schedule information supplied by rail operations. Initial systems may use real-time closures detected by field equipment to anticipate closures down the line with little or no additional coordination with rail operations. • Data Generated: Forecast closure times and durations for area grade crossings. • Automation: Manual systems which notify highway officials of planned maintenance impacting normal HRI operation. Various degrees of automation up to fully automated sharing of pertinent schedule information between railroads and agencies.

4.5.2 Transit Management Design Options

The National Architecture provides a framework that accommodates a wide range of system designs and technologies. By giving the local implementor the widest range of possible functions and data flows, and defining open interfaces between critical systems, the architecture may accommodate virtually any open system design. Table 4.5-2 shows several major design variations that are consistent with the architecture.

Table 4.5-2: Major Transit Management Design Options

Market Package	**Major Options Consistent with the National Architecture**
Transit Vehicle Tracking	• Technologies for vehicle location: signpost or wayside beacons, global positioning system (GPS), differential GPS, radio signal trilateration (e.g. Loran-C), dead reckoning. • Wide-area communications: cell-based, specialized mobile radio (SMR), trunked radio, other conventional two-way radio, wayside beacons. • Real-time traveler information: may be provided directly by the transit agency and/or through a third-party information provider. Wide variety of possible communications technologies
Fixed-Route Operations	• Data processing approaches: Centralized control at yard or operations center, distributed data sharing (via a local or wide-area network) between different units within the agency • Wide-area communications of short standard data messages • Short-range communications (e.g. beacon-tag) with vehicles at garage or yard for data dump to / from the vehicle as it enters or exits. • Traveler information: may be provided directly by the transit agency and/or through a third-party information provider. Wide variety of possible communications technologies
Demand-Responsive Operations	• Data processing approaches: Centralized control at yard or operations center, distributed data sharing (via a local or wide-area network) between different units within the agency • Wide-area communications of short standard data messages

	• Short-range communications with vehicles at garage/yard to allow data dump to and from the vehicle at the beginning or end of shift. • Traveler information and rider requests: may be managed directly by the transit agency and/or through a third-party information provider. Wide variety of possible communications technologies
Passenger and Fare Management	• Fare media: electronic credit or debit card, magnetic stripe, proximity card, other "smart card" technologies. • Data processing: data held on the vehicle and down-loaded off line, or may be communicated real-time to operations center
Transit Security	• Video or other surveillance data may be retained locally (e.g. on the vehicle or in the stop/station) or may be communicated back to management center
Transit Maintenance	• Vehicle condition data may be held on the vehicle and down-loaded off line, or may be communicated real-time to operations center
Multi-modal Coordination	• Approaches to signal priority: one- or two-way short-range vehicle communication with roadside beacon; similar to signal obtaining central authorization from traffic management center; short automated message from vehicle to transit management to traffic management center. • Transit probe data shared over similar interfaces as other probes: roadside elements or wide-area wireless communication

4.5.3 Traveler Information Systems Design Options

In a similar way, the national architecture supports multiple ways of providing for traveler information systems. Almost all conceivable options are supported by the architecture as identified in Table 4.5-3.

Table 4.5-3: Major Traveler Information Systems Design Options

Market Package	**Major Options Consistent with the National Architecture**
Broadcast Traveler Information	• The Information Service Provider (ISP) can be a private firm charging a fee for service basis or a part of an existing TMCs • Traffic information provided by traffic management can be from various sources, from probe vehicles or conventional loops. • The communications between users and the ISP are via FM subcarrier or cellular data broadcast, using low-cost equipment.
Interactive Traveler Information	• The ISP can be operated by the public sector, but it is most likely run by private firms on a fee-recovery basis due to the additional value of tailoring of information according to a user's request. • The communications between information service provider and users are through: two-way wide-area wireless (such as cellular digital) for mobile users, or wireline communication systems for home and office computers. • A variety of interactive devices may be used: phone, kiosk, Personal Digital Assistant, home computer, and a variety of in-vehicle devices.
Autonomous Route Guidance	• This market package relies on in-vehicle equipment that determines location, contains a map database, and interfaces with the driver to assist in enable route planning and provide detailed route guidance based on static, stored information • There is no external communication between the in-vehicle device and outside entities, except a periodical update of its map database. So the developer or manufacturer is free to develop proprietary systems, or systems may comply with open system interface standards.
Dynamic Route Guidance	• This market package uses current traffic information to guide vehicles. A device in the vehicle receives information about current traffic and road conditions and transit services from an information service provider (ISP) via FM subcarrier or cellular data broadcast.
ISP Based Route Guidance	• Routes are planned by the information service provider. An in-vehicle device submits a trip request, and the ISP replies with a trip plan. • Two way data communications are needed. Options for two-way wide-area wireless include cellular digital or FM subcarrier. • Turn by turn route guidance is provided by the ISP or by equipment on the vehicle which has data bases and location determination capability. • The infrastructure will not deliver turn by turn route guidance information through short-range wireless communication.
Integrated Transportation Management	• This market package couples the traffic control strategies of a TMC and the route guidance function of an ISP for simultaneous optimization. Heavy communications are expected between the TMC and ISP, and also between equipped vehicles and the ISP to confirm and log current route plans. • Communications between TMC and ISP are through a number of high-volume wireline communication systems, such as fiber optics or through the internet. • Communications between ISP and in-vehicle devices are mainly through cellular digital systems.
Yellow Pages and Reservation	• This market package enhances the Interactive Traveler Information package by adding infrastructure provided yellow pages and reservation capabilities. • The ISP for this service is foreseen to be operated by the private sector on a fee-recovery basis. • The design options are similar to Interactive Traveler Information.
Dynamic Ridesharing	• This market package enhances the package of Interactive Traveler Information with ridesharing information. All the hardware options for Interactive Traveler Information apply here. The user should be need additional equipment.
In-Vehicle Signing	• This market package supports local distribution of information regarding immediate roadway conditions. It includes a means of short-range radio transmission from the roadway to the vehicles, such as beacons, and wireline or wireless connection between the TMC and the roadway sign transmission device.

4.5.4 Fleet and Freight Management Systems Design Options

The major design options for Fleet and Freight Management Systems are listed in Table 4.5-4. Each of the options requires substantial coordination and negotiation among government agencies, who are concerned about customs, safety, taxation and licensing functions, and private companies, who are concerned about customer service, efficiency and cost. The National Architecture provides a high-level framework for communication and coordination between freight operators and government agencies. This framework is supplemented by the Commercial Vehicle Information Systems Network (CVISN) program which provides additional architectural detail and offers suggestions for specific concepts for providing the necessary coordination.

An example of a specific implementation approach that is supported by the architecture is the establishment of “clearinghouses” to support inter-jurisdictional coordination between government agencies. For carriers and vehicles that operate in multiple jurisdictions, arrangements among jurisdictions can and have been made to simplify the process of applying for the credentials to operate in those jurisdictions. (e.g., International Registration Program and International Fuel Tax Agreement). To simplify the coordination between jurisdictions for reconciling fees collected in one jurisdiction that are due to another jurisdiction, several jurisdictional associations are pursuing the establishment of clearinghouses. For example, as envisioned, the IRP Clearinghouse will collect approved IRP registration information from member jurisdictions, compute the allocation of IRP fees due to each jurisdiction, initiate the transfer of funds among jurisdictions, and provide summaries to the member jurisdictions. This represents one possible implementation strategy for the interchange between jurisdictions that is generically modeled as a Commercial Vehicle Administration Subsystem interface in the National Architecture.

Table 4.5-4: Major Fleet and Freight Management Systems Design Options

Market Package	**Major Options Consistent with the National Architecture**
Fleet Administration	• Performs administrative and operational functions necessary to operate a commercial vehicle fleet. • Functions include: vehicle dispatching and routing, processing vehicle location data, processing and storing regulatory data (permits, fuel usage by state, driver hours-of-service, driver pull notice, etc., with the exception of fleet maintenance) and responding to requests for assistance from drivers. • Communication between vehicles and the Fleet Management Center can be through a cell-based digital system, satellite data link, or preexisting wireless infrastructure. • Information flow between the Fleet Management Center and vehicles is tailored to need. • A Fleet Management Center may connect to Intermodal Transportation Providers to coordinate trans-shipments. • A Fleet Management Center may connect to its Freight Management system to support freight billing and shipment tracking. • A Fleet Management Center may connect to an Information Service Provider to obtain optimal vehicle routes.
Freight Administration	• Tracks cargo and cargo condition and supports billing. • Communication from vehicles to the Freight Management Center can be through a cell-based digital system, satellite data link, or pre-existing wireless infrastructure, and is used to transmit cargo status. • A Freight Management Center may connect to intermodal shippers and freight depots via existing wireline infrastructure in order to track cargo and transmit shipment documents.
Electronic Clearance	• Enables commercial vehicles to pass inspection facilities at highway speeds. • Vehicle transponder communicates with the inspection facility to determine if clearance status is granted. Different dedicated short range wireless systems can be selected. • Transponder can communicate vehicle, driver and carrier identification and status to the inspection facility. • The roadside inspection facility communicates with Commercial Vehicle Administrator via existing wireline infrastructure to transmit credential requests, credential responses and database updates.

Market Package	Major Options Consistent with the National Architecture
	• Electronic clearance can be extended to support International Electronic Clearance through coordination with customs, immigration and agriculture activities. • Electronic clearance equipment may be combined with weigh-in-motion and safety inspection equipment.
CV Administrative Processes	• Supports registration (electronic credential and tax filings) of drivers, vehicles, and carriers in electronic clearance programs. • The primary communication linkage is between Fleet and Freight Management and Commercial Vehicle Administration and between Commercial Vehicle Administration Subsystems. Fleet managers submit applications, and the Commercial Vehicle Administrator issues credentials and a compliance review report via existing wireline infrastructure. • Coordination among multiple Commerical Vehicle Administrators (jurisdictions) may be implemented using clearinghouses, peer to peer networks, or other strategies. See supporting text. • Commercial Vehicle Administrators send payment requests to and receive transactions reports from financial institutions.
International Border Electronic Clearance	• Automates clearance specific to international border crossings. • Provides an interface with customs and related functions and provides pre-clearance for shipment crossing NAFTA borders. • Hardware design options are similar to Electronic Clearance. • Requires agreements between Commercial Vehicle Administrator, customs, and agriculture agencies in the United States and other NAFTA countries.
Weight-in-Motion	• Provides high-speed weigh-in-motion with or without Automatic Vehicle Identification attachment. • Additional equipment is provided at roadside facilities, either fixed or mobile. • Can operate in conjunction with Automated Vehicle Identification equipment as a part of Electronic Clearance package, which may affect clearance message communicated to vehicle. • It can be used as a stand-alone system; commercial vehicles do not need any equipment and will be pulled over by signs or radio when necessary.
Roadside CVO Safety	• Automates roadside safety monitoring, inspection and reporting. • Capabilities are shared with On-Board CVO Safety Market Package. • Basic option provides access to vehicle, driver and carrier safety and maintenance records. Identification and status information are read from electronic tags of vehicles pulled in for inspection. Package communicates with Commercial Vehicle Administrator via landline infrastructure to access additional safety data • Advanced implementations access additional vehicle safety monitoring systems placed on the vehicle.
On-Board CVO Safety	• Provides for on-board commercial vehicle safety monitoring and reporting. • Supports Roadside CVO Safety market package and includes roadside support for reading on-board safety data via tags. • Uses the same communication links as the Roadside CVO Safety market package, and provides the commercial vehicle with a cellular link (data and possibly voice) to the Fleet and Freight Management and Emergency Management Centers. • Safety warnings are provided to the driver, who may be required to notify the Fleet and Freight Management and Commercial Vehicle Check roadside elements. • As an option, alerts driver of need for Preventive Maintenance or inspection.
CVO Fleet Maintenance	• Supports maintenance and regulation of CVO fleet vehicles. • Dates, mileage and results from inspections, repairs, and component replacements are stored. Records of vehicle safety violations are maintained. Preventive maintenance schedule is maintained. • Interface s with on-board monitoring and diagnostic equipment. • Data are formatted to meet regulatory requirements for vehicle and terminal inspections. • Options include transmitting vehicle status while en route through wireless means, or storing the data on-board and downloading when the vehicle arrives at a terminal.
HAZMAT Management	• Provides electronic application/issuance for HAZMAT credentials, electronic notification of hazardous material incidents and provides cargo characteristics and clean-up procedures to emergency management personnel. • Emergency notification is provided from the vehicle by a cell-based digital system, satellite data link, or preexisting wireless infrastructure. • Vehicles communicate to Emergency Management either directly or via Fleet Management. • Credential applications are transmitted from Freight Management to Commercial Vehicle Administrators and electronic credentials are transmitted back. • As an option, vehicles may store cargo manifests and cleanup procedures electronically; emergency management personnel download this information on-site. • As an option, Freight Management electronically stores cargo manifests and cleanup procedures and emergency management personnel access these data via existing wireline infrastructure.

4.5.5 Emergency Management Design Options

Major design options for Emergency Management are described in Table 4.5-5. Detailed arrangements for the initiation and reception of emergency notification is subject to regional coordination and negotiation. The private sector may also participate in this function as an initial filter for emergency calls.

Table 4.5-5: Major Emergency Management Design Options

Market Package	**Major Options Consistent with the National Architecture**
Emergency Response	• This market package automates the dispatch of emergency vehicle upon verification of incident, location, and nature of incident by the Emergency Management center. • Existing or emerging wireline interconnects to sensors are used for incident detection. • Mayday signals will be received via wirelines from other centers or from phone lines. • Instructions are provided to emergency vehicles via existing links or added cell based links between the emergency vehicle and the Emergency Management Center. • Emergency vehicle have short wave RF links to allow for local signal preemption. The Emergency Management Center would include hardware and software for tracking the emergency vehicles.
Emergency Routing	• Emergency Routing utilizes the optimal route, supplied by the ISP, to provide dynamic routing of emergency vehicles and coordination with TMS for green wave functions and ISP for best route. • Emergency vehicles can either preempt signals or request the TMC to provide greenwave through coordinated signal control (this will most likely happen during major emergencies.) • Emergency Management may either provide route plans based on their experience or forward route requests to an ISP to generate route plans based on dynamic traffic information. • Existing wireless communication systems or cell-based digital systems may be used for the communications between emergency vehicles and the emergency management.
Mayday Support	• This market package allows the user (driver or non-driver) to initiate a request for emergency assistance and enables the Emergency Management Center (EMC) to locate the user for efficient dispatch. • The request may be manually initiated or automated and linked to vehicle sensors. • The data is sent to the EMC using a cellular data link with voice as an option. • Providing user location implies either a location technology within the user device or location determination within the communications infrastructure.

4.5.6 Assessment of Communication Systems and Technologies

A common theme across each of the previous design option tables is the National Architecture's capacity to support a range of alternative communications systems and technologies. Ultimately, the system designer is faced with making a choice among these alternatives. Section 7 of the Communications Document reviews the various communications technologies that are applicable to ITS implementations. A summary of this analysis is included here to assist the state and local implementor in making communications choices that best match their needs and budgetary constraints. This information provides a broad perspective of existing technologies that must be supplemented with further research and local insight to select a "best" communications solution for a particular ITS application in a given regional setting. Refer to section 7 in the Communications Document for additional information on alternative communications systems and technologies.

4.5.6.1 Land Mobile Cellular TypeNetworks

Terrestrial-based wireless systems, listed in Table 4.5-6, are less expensive and offer a larger capacity than satellite systems. The geographic coverage area with these systems is smaller than a satellite footprint, although the majority of the population may be covered Note that, for mobile systems, coverage is based on population zones (Points-of-Presence, or POPs) rather than actual physical terrain.

Table 4.5-6 Land Mobile Cellular Type Networks

System	Targeted Applications	Services	Data Rate & Throughput	Packet Size	Typical Messaging Service Cost	Typical Mobile Unit Cost	Percentage Coverage
ARDIS	Business communication services, field service, police, taxi companies	two-way messaging, fax, email, aplha numeric paging	4.8 & (19.2 kbps in the to 15 markets) 2.8 & 4.8 kbps throughput	240 bytes	$69 / Month for 250 messages + 28 cents for each additional. message + $1/page for faxing	$500 + $50 activation fee	400 metropolitan areas about 80% of US population
CDPD	Business communication efficient exchange of data over current freqs and infrastructure	two-way messaging, broadcast and multicast (data/voice units are planned)	burst rate of 19.2 Kbps	128 bytes	1-2 cent / packet $15-$45 / month (McCaw, GTE)	$220 PCMCIA FAX modem $850 Wireless PDA	Selected US Cities; 90% of the US population by 1996
RAM	Business communication services, field service, police, taxi companies	two-way messaging dispatching broadcast	8 kbps 2.8 & 4.8 kbps throughput	240 bytes	for group broadcast messages $700 / month port connection fee 12.5 cents for 488-512 bytes for x.25 gateway connection support $125/ month + $66 for 200 Kbyte (for 33 cents for each additional Kbyte) + long-distance carrier charge	$800+ $50 activ.. fee	6300 US cites 90% of business population
ESMR	Business communication services, voice, data (competition with cellular wireless data)	two-way messaging dispatch, voice	4.8 kbps for 1996 and latter at 19.2 Kbps	initially circuit switched eventually packet switched 140 char /packet	$5 /month and 10 cents per message *Monthly fee not-available*	$900	California, Colorado & (Chicago, New York, Org, & Seattle) 70 miles cell size (25X more area than cellular)

4.5.6.2 Satellite Networks

In the next few years, many companies are planning to launch hundreds of satellites designed to provide wireless communications to mobile users virtually anywhere on the globe. Most of the mobile satellite systems are low earth orbit (LEO) systems, which are much closer to the earth than the geosynchronous (GEO) satellites normally used for telecommunications. Because of their proximity to earth, LEO systems accommodate low-powered and compact user terminals, thereby reducing time delay significantly.

Most of the satellite systems will also offer position determination. The different systems will determine the position of the user by various techniques, some more accurate than others. Even without a radio location service built into the system, the user terminal may be integrated with a GPS engine. Table 4.5-7 summarizes many of the attributes of the operational and projected satellite services, including the available cost information. It should be noted that service availability dates and costs are based on operators' projections and are typically quite optimistic.

Table 4.5-7 Satellite Networks

Satellite System	Targetted Applications	Services Planned	Coverage	Data Flow	Multiplexing
Constellation (formerly Aries) by CCI; big LEO	extension of the cellular network	voice, data and radiopaging	global (without inter-satellite linking)	1000 voice channels / satellite, 48 satellites	FDMA gateway Earth station up, CDMA user up, TDMA
Globalstar by Loral / Qualcom ; big LEO	worlwide mobile communicatio	voice initially, data to be added, also location through GPS	'seamless' global, (without inter-satellite linking)	9600 to 1200 bps, variable rate, voice activated transmission, est. 134,400 simultaneous global full duplex channels	CDMA
Iridium by Motorola; big LEO	worldwide mobile communicatio	voice, data, and location	seamless global, with intersatellite links	2400 bps	FDMA / TDMA
Teledesic by Teledesic Corp.; big LEO	ISDN to rural businesses remote terminals (non-mobile)	voice and data	95% of the Earth, with intersatelite links	16 Kbps channel rate, channels be combined to 50 Mbps; simultaneous duplex utilizes ATM fast-packet switching	FDMA / TDMA
Ellipso by Ellipsat; elliptical orbit	extension of the cellular network	voice, data, and radiopaging	peak capacity to highly populated areas during daylight hours	N / A	CDMA
Odyssey by TRW (MEO)	extension of the cellular network	voice, data, RDSS	global through 12 MEOs	2300 full duplex voice circuits / satellite, 12 satellites	CDMA
Skycell by AMSC (GEO)	transportation, maritime, aeronaturical, remote-site industries	voice, data and position location	North America (inc. Hawaii and Caribbean), through 3	N / A	CDMA
Orbcom by OSC; little LEO	emergenc comm., 2 way - mail, rem. resrce. monitorin	low duty cycle data, location through GPS	virtually worldwide through 26 LEOs	6 2400 bps channels / satellite for uplink, 2 4800 bps channels / satellite to gateway earth station; packet switched	FDMA
Starsys by NACLS, Inc. and ST Systems; little LEO	emergenc comm., asset recovery, haz. mat. tracking	location determination and low-rate data service	aimed at US and Canadian market	data sent in 100 ms	Hybrid FDMA / SSMA

Table 4.5-7 Satellite Networks (Continued)

System	First Launch	Initial Serv.	Planned Spectrum Band	Spectrum Licensed by FCC	System Cost	% of Finance Obtnd.	Cost of Service	Cost of Mobile Unit
Constellation	N/A	1998	N/A	N/A	$1.2 billion	N/A	N/A	N/A
Globalstar	N/A	1999	user - satellite: 1610-1625.5 MHz (uplk) 2483.5-2500 MHz (dwn) gateway - satellite: 6484-6541.5 MHz (uplk) 5158.5-5216 MHz (dwn)	pending	$1.5 billion	15%	$0.50 / minute	$700
Iridium	1996	1998	user - satellite: L Band sat - sat, sat - gateway: Ka Band	5.15 MHz in L-Band (tentative)	$3.4 billion	30%	$3 / minute	$3000 (w/ cellular cap.)
Teledesic	N/A	2001	400 MHz in 20/30 GHz band	pending	$9 billion	N/A	4cents/min. (projected)	$1000 - 8000
Ellipso	1996	1996	N/A	experimental	$280 million	N/A	equivalent to cellular	$300 add-on to a digital cellular unit
Odyssey	N/A	1998	N/A	N/A	$800 million	N/A	N/A	N/A
Skycell	1994	1994	1545-1559 MHz 1646.5-1660.5 MHz	full and complete	$500 million	80%	$1.45 / minute	$1800, cell/sat capable (5-6W, 2ft. antenna)
Orbcomm	1995	1995	137-150 MHz (VHF)	pending	$150 million	100%	$1 / short message	$700 initially
Starsys	N/A	1995	N/A	N/A	$300 million	N/A	N/A	N/A

4.5.6.3 Broadcast Systems

Presently, several different “high data rate” FM subcarrier systems are contending for national acceptance, while RBDS is already standardized (and available) for lower data rates. Table 4.5-8 summarizes the key features of the projected and operational FM subcarrier broadcast systems.

All high data rate systems that are identified in the table (HSDS, STIC, and DARC) use proprietary hardware and interfaces, whereas RBDS uses a standard open interface. Using a system with a proprietary interface will impact the national inter-operability for the ITS services. The main issue in deploying FM subcarrier systems will be the need for standardizing the interface and achieving inter-operability between competing proprietary systems. Each of the three high data rate systems have been submitted for standardization by the NAB and testing by the National Radio Systems Committee is in progress.

A subset of the ITS services that will not require high data rate can be broadcast using RBDS. Since RBDS has been standardized, those ITS services could easily achieve national inter-operability.

Table 4.5-8: Summary of Broadcast System Specifications

Broadcast System	**Status / Technology Maturity**	**Interface issues**	**Implementation**	**Special Features & Tech. for combating channels effects (e.g., multipath)**	**Data Rate**	**Inf. Rate**
RBDS	Operational / Commercial	Open	Commercial		1187 bps	300 bps
STIC	Prototype/ Ready for deployment	Proprietary, licenced for free in U.S.	Prototype	Uses coding, interleaving & correlation techniques.	18.8 kbps	7.6 kbps
DARC	Operational / Commercial	Proprietary	Commercial		19 kbps	8 kbps
SEIKO, HSDS	Operational / Commercial (Oregon, LA, Seattle)	Proprietary	Commercial	Freq. and time diversity: scans for 7 Station, multiple transmission of the message, time offset between stations	19 kbps	7.5 kbps

Note: RBDS can co-exist with High Speed FM subcarrier systems.

High speed FM Subcarrier Data System (HSDS)

The Seiko's HSDS system has a flexible, one-way, communication protocol. It can operate as a stand-alone single station, or as multiple systems operating independently in a geographical area. Multiple stations are accommodated using frequency agile receivers, time offset message transmission on each station, and transmitted lists of the stations surrounding each station. Reliability is improved by multiple transmission of messages.

Subcarrier Traffic Information Channel (STIC)

In early 1992 FHWA sponsored a research and development project for developing a high data rate subcarrier technology. MITRE/FHWA developed a high data rate subcarrier data system, and implemented a proof-of-concept prototype. The system is called Subcarrier Traffic Information system (STIC). STIC uses a complex data, and modulation format for defeating the multipath and other propagation effects.

Data Radio Channel (DARC) system

Digital DJ Inc. and NHK of Japan are partners in developing the FM Subcarrier Information Services (FMSS) for US applications. This system uses the data radio channel (DARC) technology, that has been developed by NHK Laboratories, for broadcasting 16 kbps data using FM subcarrier. DARC uses level controlled minimum shift keying (L-MSK) modulation format.

4.5.6.4 Dedicated Short-Range Communications

In the National Architecture, some data flows are handled by a short-range wireless interface (identified as u_2), typically involving a beacon installed at the roadside and a transponder in the vehicle.

There are three candidate technologies for the short range wireless communication link (u_2). These are active RF, passive (modulated backscatter) RF and infrared. Although each of the underlying technologies is capable of a wide range of technical performance, the comparison is restricted to the specific features which have been commercially implemented, and to varying degrees, incorporated into standards for each technology.

A number of vendors have produced or are proposing active RF vehicle-to-roadside communications (VCR) equipment. These systems are generally proprietary and not interoperable. Among the applicable standards are a draft version of “Electronic Toll and Traffic Management (ETTM) User Requirements for Future National Interoperability” prepared by the ETTM User Group of the Standards and Protocols Committee of ITS America and a draft “Standard for Dedicated, Short Range Two-Way Vehicle to Roadside Communications Equipment” being prepared by the ASTM.

From a purely technical standpoint active RF beacons have a number of advantages over passive RF beacons.Among these are:

- The use of an active tag inherently gives greater range for the same reader transmit power and antenna gain.This facilitates covering traffic in multiple lanes with a single reader
- The use of TDMA with reservation slotted-Aloha access protocol allows simultaneous handling of a larger population of vehicle tags. This also facilitates covering traffic in multiple lanes with a single reader.
- The larger packets (512 bits versus 128 bits) used in active RF give more flexibility for applications which may require greater data transfer than electronic toll collection.

On the other hand, passive RF systems offer the advantage of lower cost tags.In fact tags are available which obtain all of their power from the received RF signal and hence require neither a self-contained battery nor connection to the vehicle electrical system. At this point in time limited data is available on the performance of infrared beacons; therefore it is difficult to compare them with either of the RF technologies.

Table 4.5-9 Parameters of Beacon Technologies

System	Maximum Range	Data Rate	Transmit Block Size	Tag Data Storage
Active RF	200 ft	550 kbps	512 bits	not known
Passive RF	75 to 100 ft (with extended range reader)*	300 kbps (600 kbps optional)	128 bits	20 frames of 128 bits
Infrared	not known	125 kbps	256 bytes (forward), 128 bytes (reverse)	not known

* exact range depends on antenna gain and power setting

4.5.6.5 Wireline Communications

Wireline network options include the use of private networks, public shared networks, or a mixture of the two. Examples of private network technologies are twisted pair cables, FDDI over fiber optic rings, SONET fiber optic networks, and ATM over SONET networks.Examples of public shared network options are the leasing of telco-offered services such as leased analog lines, frame relay, ISDN, metropolitan Ethernet, and Internet.A third Wireline network option category is a mixed network, where existing communications infrastructure can be utilized to the greatest extent possible, and possibly upgraded to carry any increased data load.The addition of CCTV in particular can overload the backbone of an existing network.

The decision to specify a private network is probably not motivated by technological reasons because the desired data bandwidth can be supplied through the use of public shared networks.It is certain that in the time frames studied that one or more local carriers can provide a network connectivity to fulfill the ITS requirements. Some reasons for building a private network are to have a network built to the exact specifications of the user, and to match the funding mechanism. If one-time capital funding is more easily obtained than monthly lease fees, then a private network is the best choice.There will still be an ongoing maintenance cost though.

The active participation of the owners of the roadway right of ways in partnership with one or more commercial carriers may be a means of having a private network built for the ITS infrastructure at little or no cost to the local agency. In exchange for the use of the rights of way, the carriers would provide a portion of the network capacity for ITS use, and much of the maintenance cost.

Table 4.5-10 Widely Available Public Network Technologies

Link Technology	**Analog Leased Lines**	**Digital Leased Lines**	**Frame Relay**	**ISDN**	**SMDS**
Type of service	Dedicated circuit	Dedicated circuit	Packet switched	Circuit switched and packet	Packet switched
Transmission medium	Standard telephone line	Digital facilities	standard telephone line to four-wire T1 technology	basic rate ISDN - standard telephone lines; primary rate ISDN - four-wire T1 technology	four-wire T1, and fiber optics
Data rate	up to 19.2	2.4 Kbps, 64 Kbps, fractional T!, T1 (1.5 Mbps), T3 (4.5Mbps), DS3 (45 Mbps)	56 Kbps up to T1	Circuit switched B channel 64 Kbps, packet D channel 16 Kbps; basic rate ISDN=2B+D, primary rate ISDN=23B+D	T1, T3, SONET to 155 Mbps
Capabilities	point-to-point and multipoint	point-to-point and multipoint	Suitable for data only.	B channel well suited for CCTV which can be used intermittently, D channel for simultaneous data	Suitable for data only.
Comments	Universally available	High reliability	Fixed monthly charge based on data rate	Cost is usage dependent	Cost is usage dependent
Cost/month (rough estimate)		56 Kbps: $300/month; T1: $3.50/month/mile +$2500/month; DS3: $45/mile/month+$ 16000/month	56 Kbps:$175/month T1: $435/month	basic rate ISDN:$40/month + $0.57/kilopacket for data and $0.016/minute for B channel	

4.6 Evaluating Existing Systems

In the preceding material in section 4, the focus has been on planning and implementing new ITS systems and the National Architecture implications for these systems. This section discusses the National Architecture implications for ITS systems after they have been deployed.

The National Architecture is relevant to the evaluation of existing ITS systems from two perspectives:

1. The National Architecture defines a Planning Subsystem which is intended to facilitate the collection of operational data for the purpose of evaluating existing systems and planning for future improvements. Specifying these interfaces in new system implementations can enhance future evaluations and planning in the region.
2. The evaluation of existing systems may include a measure of their compatibility with the National (or Regional) Architecture. While not a primary focus of the evaluation process, which is on measuring operational performance, the ability to measure compatibility with the National Architecture may also be useful depending on the original requirements levied on the system.

4.6.1 Using the Planning Subsystem

The National Architecture defines an interface between each of the center subsystems (e.g., traffic management subsystem, transit management subsystem) and the Planning Subsystem. The messages defined for this interface are intended to support off-line collection of various performance measures that are accumulated and passed along during system operation. As standards governing this Planning Subsystem interface are identified and included in new procurement specifications, data collection for the purposes of evaluating existing system performance and exploring new implementation options will be facilitated. Before such standards are available, positive steps can be taken to achieve some of these benefits simply by understanding the traffic simulations and planning models currently in use in the region and requiring special reports that can be generated by the operational system that provide data formats that can be imported directly into these tools. As the models and simulations incorporate more ITS capabilities, tangible improvements in the quantity and quality of data available to the planners will be possible.

4.6.2 Assessing Compatibility with the National Architecture

As the National Architecture Development Program progressed and the Architecture definition stabilized, the Architecture Development team focused on how Architecture compatibility could be measured. Such consideration is warranted since, even before the conclusion of the Architecture Development, National Architecture compatibility requirements have started to appear in various ITS procurements.

Unfortunately, all the information that is necessary to perform a complete and objective assessment of National Architecture compatibility is not available today. The Architecture is an iterative product intended to support identification of applicable industry standards and the need for development of new ITS application standards. For this reason, a complete assessment of Architecture compatibility can only be made after the necessary standards are developed.

As the standards work progresses, the standards development organizations are sure to enhance the interface definitions initially provided by the Architecture. Many of these enhancements can be expected to be expansions to the high-level definitions provided by the consensus Architecture. In other cases, the higher level architecture definition itself may be affected as the standards committees do their detailed work. To assess Architecture compatibility with certainty today would require an accurate forecast of what the final standards will be – clearly something that cannot be predicted.

Before standards are available, any measure of consistency with the National Architecture is more qualitative and subject to change. In this interim period, comparing the Architecture to regional deployments is still beneficial since it provides visibility into the proposed interface requirements and standards that may be pertinent in the future. Potential benefits of this insight are cited below.

- Implementation options that are not supported by the Architecture will be revealed. Early resolution can then include either correcting the omission in the Architecture through planned Architecture maintenance and standards development efforts, or by adjusting the system design.
- Upcoming standards development efforts which may impact the deployment will become apparent. The concerned implementor can then participate in the standards development process to ensure local interests are reflected in the evolving standards.
- New system designs can be partitioned to reflect the identified interfaces so that the system may be cost-effectively upgraded in the future.
- Standards development efforts can be considered in planning and programming future transportation improvements.

The same correlation between the existing regional systems and National Architecture subsystems that was used to generate the regional architecture in section 4.3 is used to evaluate an existing system. Through this process, the regional transportation systems are aligned with the National Architecture subsystems and the data flows between National Architecture subsystems are associated with particular regional interfaces. Using this mapping as a basis for the comparison, an evaluator could verify that the regional system:

- Supports the functions defined for the associated subsystems and applicable market packages or user services.
- Supports the data flows that are passed between the associated subsystems for the applicable market packages or user services.
- Uses open standard interfaces wherever they exist. Use of proprietary interfaces or communications protocols may also be appropriate; especially for near-term implementations when viable open standards may be immature or non-existent.

The final bullet represents good practice that can begin to provide immediate benefits to the implementing agency and provides some market impetus to system providers to make open-standard transportation products available. The first two items require a detailed mapping which selectively applies the full specification of the National Architecture to the regional system.

Figure 4.6-1 shows the initial mapping between the National Architecture and the transportation systems in Southeast Michigan. Beginning with this mapping, the functions and data flows defined by the National Architecture may be compared with the existing system's design. Table 4.6-1 summarizes the Architecture definition for each applicable interface and compares this with the current interface usage in Southeast Michigan. The last column indicates whether the implementation being assessed is consistent with the Architecture interfaces. Consistency is indicated in the table for this example when the regional design performs the functions and passes the general types of information identified by the National Architecture for the subset of Traffic Management, Transit Management, and Traveler Information services that have been implemented in Southeast Michigan. The latitude that is allowed in such a comparison prior to availability of published standards will be variable. A more formal and rigorous definition of National Architecture conformance would be necessary to ensure conformance measures that are comparable across projects and evaluators.

A comparison between the interface requirements levied by the Architecture and the regional transportation system design in the selected example indicates that the existing ITS systems in Southeast Michigan are well aligned with the Architecture framework. Each of the major system interfaces have corresponding interface definitions in the Architecture. Also, much of the additional connectivity identified by the Architecture is clearly anticipated and planned for in the region.

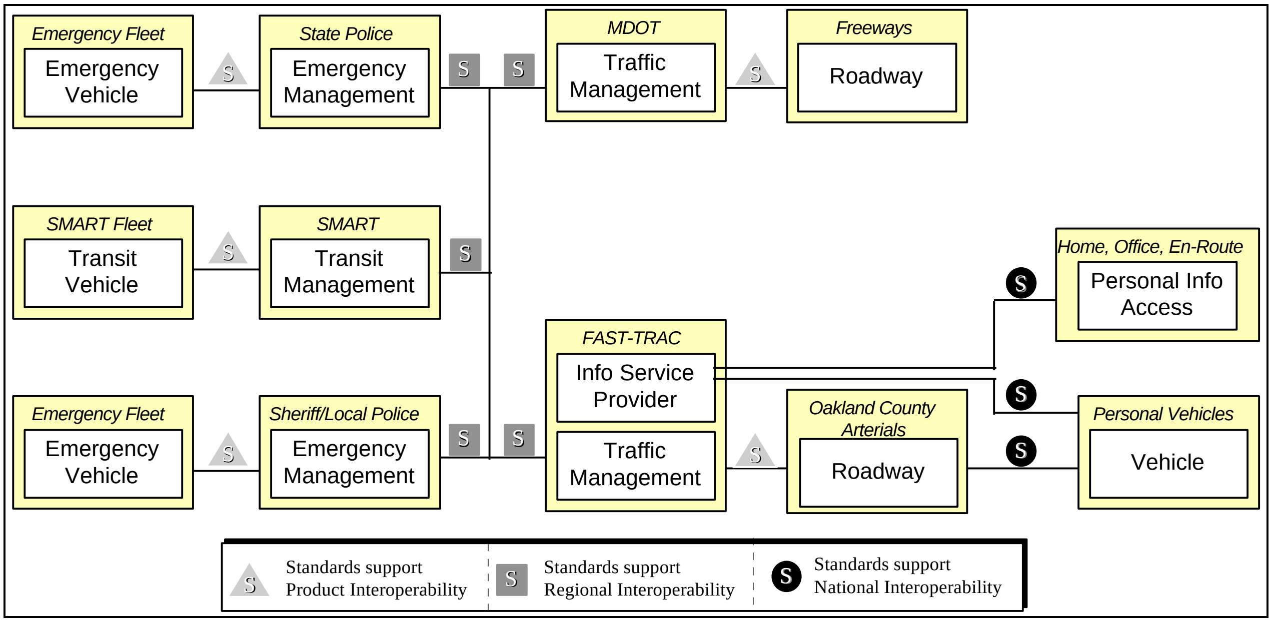


Figure 4.6-1: Applying National Architecture Interoperability Ratings to Southeast Michigan

Table 4.6-1: Assessing Southeast Michigan's Compatibility with National Architecture

Interface	Interface Description	Standardization Benefit	Consistent?

Interface	Interface Description	Standardization Benefit	Consistent?
Emergency Mgmt to			
S Emergency Vehicle	Wide-area communication of vehicle status and operations monitoring actions between dispatch and driver.	Open standard on interface enhances choice between suppliers. Regional adoption of the same standard enhances ability for regional coordination and enhances interoperability between agencies and geographic areas in emergencies.	YES
Traffic Mgmt to S Emergency Management	Exchange of incident status information supporting early identification and rapid and appropriate coordinated response.	Standard facilitates interoperability between diverse response agencies and potentially distributed traffic management centers within a region.	YES
S Information Service Provider	Initially enables sharing of real-time traffic information. Interface supports transfer of raw traffic data, processed measures of effectiveness, with associated data quality attributes. Advanced service shares OD pairs enabling system optimal strategies.	Facilitates entry and competition among private information providers enhancing service to travelers and revenue opportunities for traffic management subsystems.	YES
S Traffic Management	Exchange of traffic information, advisories, and control data between traffic management subsystems. Supports coordination between neighboring jurisdictions and between freeways and arterials.	Many agencies and jurisdictions may be integrated in institutionally complex metropolitan areas. Standard reduces development costs as existing autonomous systems are integrated and new systems are brought on-line.	YES
S Transit Management	Exchange of traffic information, transit service status, and traffic control data between traffic and transit management. Supports coordination in determining signal priority for transit vehicles.	Many agencies and jurisdictions may be integrated in institutionally complex metropolitan areas. Standard reduces development costs as existing autonomous systems are integrated and new systems are brought on-line.	YES
Transit Mgmt to			
S Transit Vehicle	Wide-area communication of vehicle status and operations monitoring actions between management and driver.	Open standard on interface enhances transit agency choice between suppliers. If standards regionally or nationally adopted, enhances ability for vehicles to be shared between agencies and geographic areas when the need arises.	YES
Vehicle to			
S Roadway	Short range communication of location specific information using beacons or equivalent devices. Supports electronic toll collection, commercial vehicle operations, intersection collision avoidance, probe data collection, traveler advisories, and in-vehicle signing services.	Common interface reduces number of distinct, short range vehicle interfaces. Consistent performance across regions enhances market and is a significant safety consideration for some future services (e.g., in-vehicle signing.)	Potential Issue. Provision of route guidance info is presently not supported for this interface.
S Information Service Provider	Wide area wireless provision of traveler information. Information ranges from basic advisories regarding current traffic and road conditions through real-time route guidance, yellow pages, reservations, real-time ride matching, and other advanced interactive traveler information services. Both broadcast (e.g., FM Subcarrier) and interactive (e.g., CDPD) wide area wireless communications services are supported.	Common interface reduces the number of distinct, wide area wireless interfaces a vehicle must support (avoids the "porcupine vehicle" issue) which improves the potential for OEM vehicle products, key to stimulating larger markets. Common interface also increases the available population of probes improving data fidelity and network coverage.	YES

5. DOT Strategy Recommendations

Although implementation of ITS will ultimately be dependent on decisions by the private sector and state and local agencies, the U.S. Department of Transportation (DOT) has several important roles to play. This section distills the ITS Architecture and market package definitions from section 2, the public sector and private sector roles forecast in section 3, the specific state and local implementation guidance provided in section 4, and derives a set of recommendations for the DOT that are intended to facilitate implementation of ITS architecture compatible systems.

Perhaps the most salient DOT role relative to the architecture is in ensuring interoperability at the inter-regional and national levels. Section 5.1 provides a series of recommendations to this end. In addition, various agencies participate in promulgating, implementing and enforcing various rules, regulations, and standards aimed at ensuring the safety of travelers, as well as ensuring fair competition in the provision of private sector goods and services. Section 5.2 highlights policy recommendations relevant to the DOT role as a source for transportation policy. Finally, the DOT has an ongoing stewardship role in providing continued support to localities on ITS research, development and deployment. Section 5.3 suggests the various investments that can be made by the US DOT to promote rapid, successful ITS deployments in order to realize the full benefits of ITS.

5.1 Towards National Compatibility and Interoperability

National compatibility and interoperability is a key issue for both consumers and producers. For consumers, interoperability makes ITS usage convenient and seamless. Products and services procured in one area of the country should be functional in other areas of the country. From the producer's vantage point, standardization can assist in consolidating markets and developing economies of scale, thereby increasing the likelihood for early deployment of ITS services.

Notwithstanding the benefits of interoperability, setting standards during periods of rapid technological change can entail certain risks. Early adoption of existing standards--while it can ensure interoperability--can also "lock" the system into inferior products and delay adoption of new technologies in the future. For this reason, the National Architecture identifies those areas that are candidates for standards and encourages the appropriate processes to ensure that the standards are developed in a fair and time-appropriate manner.

This section addresses public sector activities that can be undertaken to enable achievement of national interoperability and compatibility goals. Recognizing that reaching these goals extends beyond standards development, this section also addresses activities that: 1) Encourage beneficial adoption of standards by stakeholders, 2) Enable stakeholders to assess compatibility, and 3) Maintain the National Architecture.

5.1.1 Expedite and Coordinate Development of Critical ITS Standards

The most apparent and near-term activity that is supported by the National Architecture is subsequent development of the priority standards as identified in the Standards Development Plan. US DOT has already performed a series of steps intended to expedite this effort. Multiple contracts have been awarded to Standards Development Organizations (AASHTO, IEEE, ITE, SAE, and ASTM.). Through these contracts, the US DOT will expedite the development of selected standards relevant to ITS with special emphasis on those areas required to support the Intelligent Transportation Infrastructure initiative. These standards development efforts will not start from scratch. In many cases, broader standards exist which directly enable ITS deployments (e.g., Internet standards have been a recent catalyst for many traveler information system deployments). In other cases, existing standards provide a basis for more specific ITS standards (e.g., Structured Query Language and EDIFACT may be applied to standards focused on ITS applications).

A second continuing role for US DOT is to assist in coordination of these on-going standards efforts. The National Architecture, and the JPL-developed inventory of ITS-relevant standards efforts provide a natural starting point for this coordination effort. The current vision is directed towards development of a world wide web site, perhaps as an extension to the ITS America site or another site which features ITS-related material. The site would provide current status of the on-going standards efforts, links to other sites which host the current draft standards, and includes forum areas in which the transportation professional can offer advice on the current standardization efforts. This site would provide a key tool that can be utilized by the Council of Standards Organizations to coordinate the standards efforts and encourage broader awareness and participation among transportation stakeholders.

The Standards Development Plan is intended to complement the existing plan of action with emphasis on the National Architecture products and their most appropriate application in supporting ITS standards development. Please refer to the Standards Development Plan for additional information.

5.1.2 Selectively Encourage Standards Adoption

Given the availability of appropriate standards for ITS, the next step is to ensure that the standards are applied in transportation system implementations. In order for a standard to be adopted and used, the implementor must: 1) be aware of the standard, 2) have access to products that support the standard, and 3) must feel that the long term benefits associated with adopting the standards outweigh any up front costs associated with upgrading the system.

It is important that information regarding emerging ITS standards be made available to practitioners in transportation. Outreach, education, and training are all important to promote early awareness of emerging ITS standards. This awareness may encourage participation in the standards development process or, at least enable practitioners to make informed procurement decisions when the standards are available.

It is largely the function of the private sector to make sure that products are available to support accepted standards. In most ways, the market will take care of itself in this regard. One unique approach that has been used to encourage adoption of the NTCIP standard, the development of a public domain NTCIP software library to facilitate cost-effective adoption of the standard by financially strapped local governments, may be considered for other ITS standards that specifically address public infrastructure.

In instances where existing transportation systems are installed and working which predate the standard, there will not be a real incentive to upgrade the system solely to achieve national interoperability. Over time, such systems will be upgraded or replaced for other reasons at which time standards-compliant systems will likely be implemented.

For interfaces that are most important to national interoperability and compatibility interests, conditional funding may be considered. Standards identified in the standards development plan as promoting regional interoperability or product interoperability are not necessarily good candidates for conditional funding at the national level. Each state or region can apply pressure to ensure adoption of regional standards at its discretion. Economically justified standards (i.e., those identified as supporting product interoperability) may similarly be adopted and enforced by local implementors. Whether this enforcement or incentive is applied at the national, state, regional, or local levels, suitable standard clauses should be developed for inclusion in procurement specifications to assist implementors in procuring compatible systems.

Of course, safety standards associated with advanced vehicle systems and hazardous material systems may well be regulated at the national level. There is also precedent for legislation at the state level to impose standards that are judged to be in the state’s best interest. A current example is Assembly Bill No. 3418 requiring a standard communication protocol, derived from the draft NTCIP standard, for traffic signals in the state of California.

5.1.3 Accommodate Pre-Standards Systems

Even when facilitated, the standards development process time will be measured in years rather than months. Characteristically, there are early adopters who deploy systems as soon as implementation becomes feasible...usually some time before mature standards for the system are available. These early adopters are spurred by a pressing problem that the implementation will address and are instrumental to furthering understanding. These pioneer deployments also often directly influence the standards that are ultimately developed. Consideration must be given to bridging from these early implementations to the more interoperable, compatible, and interchangeable implementations that will be enabled by the standard. There are several different ways to accommodate pre-existing systems while incorporating new standards into the transportation system.

1. Take the existing implementations into account in developing the new standard. By maintaining backwards compatibility within the new standard, graceful transition to new implementations is supported while preserving existing investments. This approach invariably incurs complexity, cost, and/or performance penalties in the backwards compatible products. This approach is normally only applicable when existing implementations are fairly uniform and can be enumerated and factored into the new standard.

2. Operate parallel implementations during some reasonable transition period. This approach allows the new standard to have minimal overhead but does inherently limit the transition period. This approach requires the existing and new systems to be non-interfering or for the installation to preclude interference between old and new systems.

In general, there should be no requirement to replace or retrofit existing systems that are not being upgraded or replaced for other reasons.

5.1.4 Resolve Issues Regarding Conformance Testing and Certification

There is no established policy for ensuring conformance with the National Architecture at this time. Certainly, there will not be a single solution that applies to all of the interfaces encompassed by the architecture. As standards development continues and the Architecture matures as a framework for these standards, various methods with differing degrees of formality can be used to ensure a system's conformance with ITS standards.

- The standard can be published and responsibility for compliance determination can be left to the developer, implementing agency, or user. General guidance can be provided to the implementing agency or user to require demonstration of compatible operation prior to procurement.

- Additional assistance can be provided by developing and publishing suggested test and evaluation programs that are administered at the discretion of the developer, implementing agency, and/or user.

- At the next level of formalism, officially sanctioned test suites may be developed and distributed with some warranty for effectiveness in determining conformance. Passage of these tests can be required before the developer is allowed to market the system or product as conforming with the standard.

- In the most formal implementation, a formal certification program can be developed and administered by certified test sites before a product is determined to be in conformance with the standard. Such programs often require intermittent revalidation of certified product lines.

The latter, more formal processes for measuring conformance are normally reserved for standards with public safety implications. Most of the standards needs identified by the National Architecture can be implemented through the less formal mechanisms. In general, "best practice" should be supported rather than formal conformance programs. The National Architecture and the standards which follow can be viewed as tools to be applied selectively with continued sensitivity to the implementation flexibility that underlies the current architecture definition.

5.1.5 Maintain the Architecture

While every effort has been made to define a National Architecture that is resilient to change, events that will outdate the National Architecture deliverables are inevitable. Any or all of the following unpredictable developments could occur:

- The scope of ITS could be increased to include additional services.
- Some of the anticipated services may not materialize, effectively reducing the scope of ITS.
- New technologies and creative approaches for using these technologies may develop that were not anticipated by the architecture development teams. Though the architecture strives to maintain technology independence, unforeseen technological evolution may not readily be accommodated by the existing framework.
- Stakeholder subarchitectures (e.g., CVISN), standards activities, and early deployments will evolve more specific and more current definitions, supplanting and in some cases contradicting, the existing National Architecture definitions.
- Changes in the lexicon (e.g., IVHS to ITS) can date the documentation over time.

Figure 5.1-1 illustrates two very different potential responses to such events which are considered further in the following paragraphs.

Alternative #1: No Emphasis on Architecture Maintenance

In the scenario illustrated in the lower left portion of Figure 5.1-1, the National Architecture serves the same purpose as the first stage in a multi-stage rocket. It provides the initial thrust towards achieving national compatibility and interoperability goals but then falls away as more specific standards development, implementation guidance, and other deployment support activities are enabled and begin. The subsequent activities use the architecture products as initial inputs, but as these products are scrutinized, elaborated, and enhanced, a new generation of products become the focal point. Over the long term, as final standards become available and deployments increase, the National Architecture will inevitably evolve from an ITS centerpiece to a milestone of primarily historical significance.

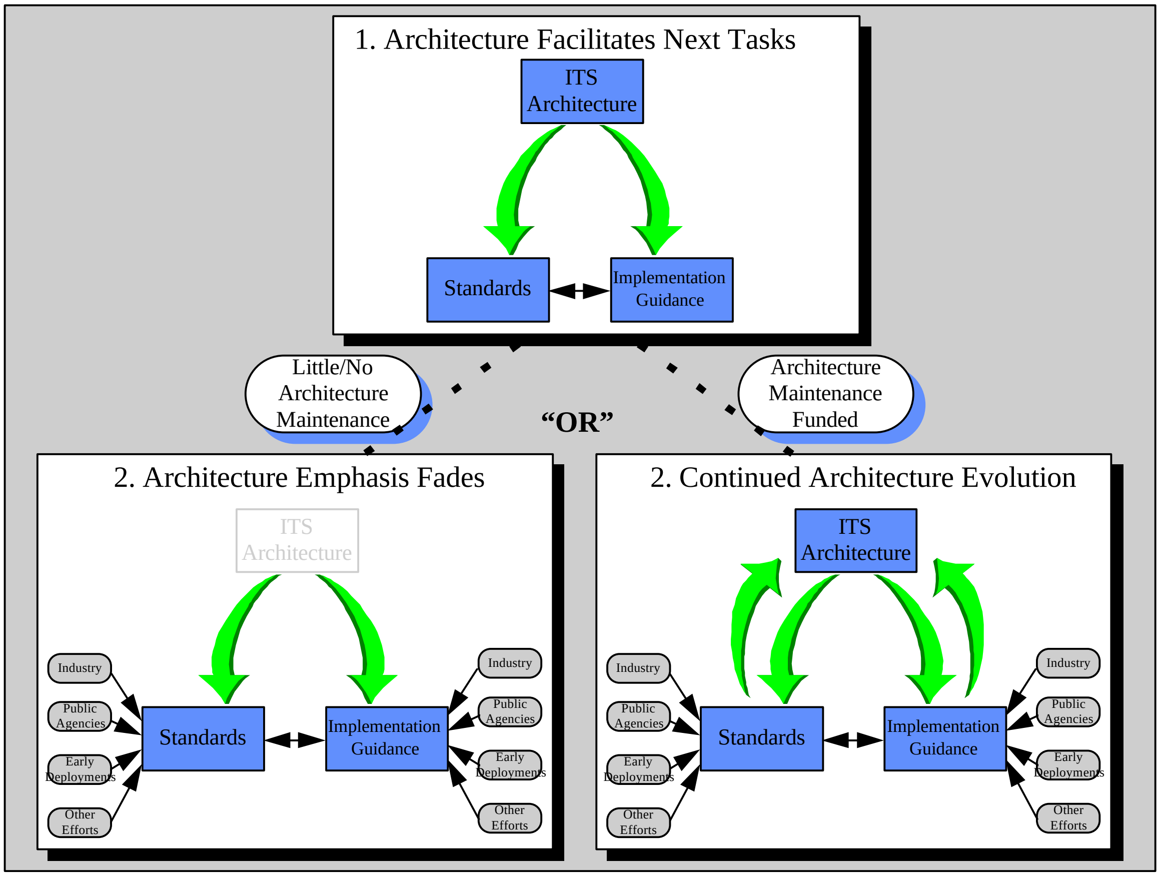


Figure 5.1-1: Considering Alternatives in Architecture Maintenance

The key question in this scenario is: "What is lost when the National Architecture products become outdated and "fall away" from the mainstream effort?". The immediate concern is for some potential loss of consistency across the various standards efforts as each works towards a narrower set of goals and requirements than that encompassed by the National Architecture.

While this is a valid concern, there are several factors that help to mitigate the associated risk.

- The National Architecture that has evolved is actually composed of several loosely coupled subarchitectures. Within each of these subarchitectures, the interactions between elements are numerous and inter-related which makes coordination very important within each subarchitecture. For instance, the interface between the Traffic Management Subsystem and the Roadway Subsystem and the interface between the Traffic Management Subsystem and other peer Traffic Management Subsystems are highly correlated and would be considered to be within the same subarchitecture.. Between subarchitectures, however, there are fewer interactions which makes changes in one subarchitecture largely transparent to the remaining portions of the national model. For instance, the interface definitions that support commercial vehicle operations have little or no relationship to the previously mentioned traffic management interfaces. Changes in the commercial vehicle interface definitions would be transparent to the interface definition work which supports Traffic Management. If consideration is given to allocating the tightly coupled standards efforts to the same organization, the integrity of the final set of standards will likely be improved even without continuous monitoring against the National Architecture documentation. Such common allocation of the most closely related efforts may be a natural by-product of the tendency for the same organizations to work areas of common interest that require common expertise.

- The open consensus process ensures that each evolving standard will be reviewed by a large number of stakeholders. This is a built-in defense against disconnects that might form with tangible negative impacts.

- Any disconnects that do occur will likely be resolved as early deployments and other tests reveal these issues and the standards are iteratively enhanced. (Although this implies possible negative impacts on those early deployments which surface the standards issues.)

Alternative #2: Continued Architecture Maintenance

In the second scenario, the National Architecture is actively maintained and updated to preserve its role as an overarching framework for ITS and to provide an evolving touchstone for overall ITS compatibility and interoperability. This approach requires a defined process for making controlled changes to the National Architecture deliverables after July, 1996. Mechanisms that consider change requests which may originate both within and outside the maintaining organization(s) should be in place. Approved changes must be implemented and communicated to interested parties. ITS America has done an initial survey of the configuration management process and its potential application to the National Architecture products.

The Architecture Team has developed procedures and automated tools for implementing and verifying controlled changes to the National Architecture baseline. These procedures and tools can be carried forward to form a basis for continued architecture maintenance. Extensions to the current suite of tools should be considered which improve the maintainer’s ability to generate accessible, automated reports itemizing proposed changes. It is expected that these reports would be made available on-line to facilitate timely review and feedback.

There are several benefits to continuing architecture maintenance, particularly during the next few years. An actively maintained architecture would:

- Allow close coordination with Standards Development Organizations as they move through the initial steps of standards development. There are few ITS standards activities which have advanced to the point of having a draft standard. Close coordination to impart not only the details, but the vision of the architecture will be essential during the initial hand-off process. As individual standards groups make progress, an actively maintained architecture could reflect changes from the SDOs so that consistency across many different subsystems is maintained.
- Support incorporation of new user services in an integrated manner into the existing architecture. Without maintaining a view of the whole architecture new services are likely to be “patched onto” the architecture rather than fully integrated with it.

- A current architecture provides a useful set of guidance documents for public and private sector implementors.
- The architecture provides a technical underpinning to DOT initiatives such as the Intelligent Transportation Infrastructure and Model Deployments. It would provide a living definition of the integration of user services sought by both of these efforts.

Pursue a Streamlined Architecture Maintenance Effort

Considering the benefits of a current National Architecture definition, what steps can be taken to streamline the effort required to maintain the architecture? Not all of the documents developed and delivered with the National Architecture program would have the same priority when considering an on-going maintenance scenario. Table 5.1-1 differentiates between the National Architecture products with regard to the long-term role they might play and the effort that might be involved in maintaining them. In the table, "Sensitivity" estimates the likelihood that on-going changes to the architecture framework would impact the subject documents. In general, the higher-level documents will be more resilient to change than the more detailed documents. The Ease of Update column indicates whether special tools and skills are required to maintain the document. Note that "Ease of Update" is not related to the number of hours that would be required to update the associated deliverable. The actual amount of effort that would be required would be situational and dependent on the scope of the change, the review requirements, and the familiarity of the maintenance organization with the document, the required change, and the associated tools.

Table 5.1-1: Streamlining Architecture Maintenance

Document	Sensitivity	Tools Required	Ease of Update	Priority
Mission Definition	Low	Desk Top Publishing	Easy	Low
Vision	Low	Desk Top Publishing	Easy	Low
Logical Architecture	High	Cadre Teamwork Desk Top Publishing	Difficult	High
Physical Architecture	High	Relational Database Desk Top Publishing	Moderate	High
Traceability Matrix	High	Relational Database Desk Top Publishing	Moderate	High
Theory of Operations	Moderate	Desk Top Publishing	Easy	Moderate
Implementation Strategy	Moderate	Desk Top Publishing	Easy	Low
Standards Development Plan	Moderate	Desk Top Publishing	Easy	Low
Standards Requirements	High	Relational Database Desk Top Publishing	Moderate	Moderate
Evaluation Plan	Low	Desk Top Publishing	Easy	Low
Risk Analysis	Low	Desk Top Publishing	Easy	Low
Performance and Benefits Study	Moderate	Desk Top Publishing	Easy	Low
Cost Analysis/Projections	High	Spreadsheet Desk Top Publishing	Moderate	Low
Communications Document	High	Desk Top Publishing	Easy	Low
Evaluatory Design	Moderate	Desk Top Publishing	Easy	Low
Executive Summary	Low	Desk Top Publishing	Easy	Moderate

In completing the “Priority” column in the above table, it was assumed that the principal continuing mission of the National Architecture is in maintaining consistency among the evolving ITS standards and in promoting their understanding and coordinated use. More elaborate objectives might require additional deliverables to be actively maintained.

Deliverables associated with a general introduction to ITS and the architecture (Mission Definition and Vision), time sensitive plans for deploying ITS (Implementation Strategy), and evaluation deliverables that do not directly support a “standards consistency” objective are identified as low priority in the table. In general, these deliverables are incorporated into, and superseded by, other plans and guidance documents that will be developed in the future. Consideration could be given to updating portions of the Implementation Strategy as a current repository of implementation guidelines. Depending on the level of interest in maintaining basic explanatory information, some level of maintenance would be required for selected introductory deliverables like the Theory of Operations or Executive Summary.

The most critical effort is in maintaining a current architecture definition. There are two basic approaches which can be used to maintain a baseline architecture definition.

1. Maintain both Logical and Physical architecture documents. This approach would require the complete representation of the architecture to be maintained along with complete traceability of functions to physical entities. This approach has the benefit of maintaining the detailed process specifications and intra-subsystem interactions defined only in the Logical Architecture. A rigorous trace of data flows between individual processes within subsystems would also be possible. The cost of this approach is that additional effort will have to be spent to maintain the Logical Architecture, most likely using the Cadre Teamwork tool.

2. Maintain only a single, physical representation of the architecture definition in an “enhanced” physical architecture document. This approach would include detailed functional specifications for each subsystem and a composite data dictionary that completely describes all messages that are exchanged between subsystems and between subsystems and terminators in the physical architecture. This approach would reduce the effort involved in maintaining a current version of the architecture while maintaining much of the product’s contribution as a top-level framework.

It is currently anticipated that the initial maintenance effort will support both Logical and Physical Architecture documents as recommended in approach #1. As the maintenance effort continues, DOT and the architecture maintainers can consider approaches similar to approach #2 that amend the architecture products to facilitate maintenance of the evolving architecture baseline farther into the future.

To establish the set of documents to be maintained, the continuing role of the Standards Requirements Document (SRD) must also be determined. The initial role of the SRD is as the primary interface to the SDOs to which it provides relatively detailed standards requirements for the selected priority interfaces. It is substantially a derivative document which repackages and elaborates the requirements contained in the other architecture definition documents. After this initial contribution is absorbed into the standards development effort, the Standards Requirements document might also be excluded from the architecture baseline to be actively maintained. If it is not maintained, the mechanism for communication between the SDOs and the National Architecture would shift towards the architecture definition deliverables combined with situational reports targeted towards the issue at hand. If the maintenance effort includes the Standards Requirements Document and updates are provided to the SDOs, then the SRD's role as an interface to the SDOs could be preserved.

It is expected that the approach that has evolved in Phase II, in which subset standards requirements documents are developed to address a particular application area or need, will continue during the maintenance phase. These reports will be situational, derived from the underlying architecture definition products, and provide a focused presentation of the architecture requirements in a given area (for instance, the standards requirements associated with Highway-Rail Intersection applications would be a likely product once the requirements from the new user service are integrated into the architecture).

5.2 Deployment Support

The National Architecture provides the framework for deployment of all the potential ITS services. Though the focus for deployment will be at the local level and in the private sector, DOT has a major role to serve. Federal policies and actions, and most importantly leadership, can provide guidance and direction to implementors. Such leadership is needed to ensure that the ITS industry achieves interoperability, that jurisdictions are coordinated at the regional level, and that ITS becomes an effective tool for solving transportation problems.

Building from the institutional issues introduced in section 3, this section recommends DOT policies for implementing the National Architecture. The section highlights results from related architecture analyses as well as from outreach efforts conducted over the course of the program. This section is supported by Section 5.3, which covers strategic investments in ITS.

5.2.1 Education and Training

A flexible, open, and distributed architecture requires greater knowledge and consideration of how best to apply the architecture to a particular location. While avoiding a “one size fits all" solution helps insure local appropriateness, it carries with it a greater requirement for educating those making deployment decisions. Such education is needed on various levels, from a policy level understanding of how to incorporate ITS architecture into overall transportation and communications investment decision-making to a detailed technical understanding of the various data-flows and their implication for local subsystem deployment.

Successful implementation of the architecture would benefit from DOT involvement in architectural training, both for its own employees and for state and local officials. The greatest benefit would come from development of curricula for training local and state officials and DOT field representatives in features of the architecture, and for training in how the National Architecture can be adapted to meet local and regional needs. These curricula should be updated periodically to reflect evolving standards. The DOT curricula should be the basis for architectural courses that can be administered by the private sector and non-profit educational institutions (DOT as well as large transportation agencies may opt to use their own employees as trainers).

<u>Long-term success may require new university curricula</u>. Traditionally, transportation courses are taught within Departments of Civil Engineering and Planning. ITS presents increasing demands for knowledge in computer science, communication engineering and system engineering. To meet long-term educational requirements, DOT should consider providing seed funding for the development of multi-disciplinary degree programs that satisfy educational requirements for future ITS professionals.

<u>Successful implementation does not require DOT leadership in developing technology training courses</u>. The technologies that support ITS market packages have evolved rapidly, and it is essential for implementors to receive frequent training and re-training. However, a variety of institutions, including university extension programs and consulting organizations, already exist to deliver such training programs. In addition, the needed skills can be obtained through contracting with the private sector and hiring employees from the private sector. Active DOT involvement is not needed to capture these benefits.

5.2.2 Cost/Benefits Assessment

Whereas the National Architecture presents a framework for ITS deployment, and the implementation strategy identifies promising ITS market packages, there remains a need to precisely quantify the benefits, impacts and cost of market packages. In addition, a strong need exists to understand benefits, impacts and costs of standardization. These assessments are needed to develop federal policy for funding ITS deployments and to provide guidance to local and state officials and the EPA on appropriate solutions to transportation problems. This need translates into the following requirements.

<u>Early deployments should collect cost, benefit and impact data (quantitative and qualitative) as an integrated requirement of the system's operation</u>. Building from the Field Operational Test program, DOT should establish uniform and ongoing mechanisms for independently collecting and evaluating data as well as for independently auditing data reported by state and local agencies. DOT should be responsible for periodically creating a cost, benefits and impacts summary for all ITS market packages, and for providing guidance as to how cost, benefits and impacts depend on local conditions. Supporting tools which facilitate local estimates and projections based on this information should also be considered.

<u>New market packages should be deployed cautiously in limited areas to increase understanding of costs, benefits and impacts before making more substantial commitments</u>. This approach is particularly true for more advanced ITS Services which have never before been deployed. Many early market packages have already been tested in operation over the last four to five years through FOTs and other early deployments. The current funding of operational tests and early

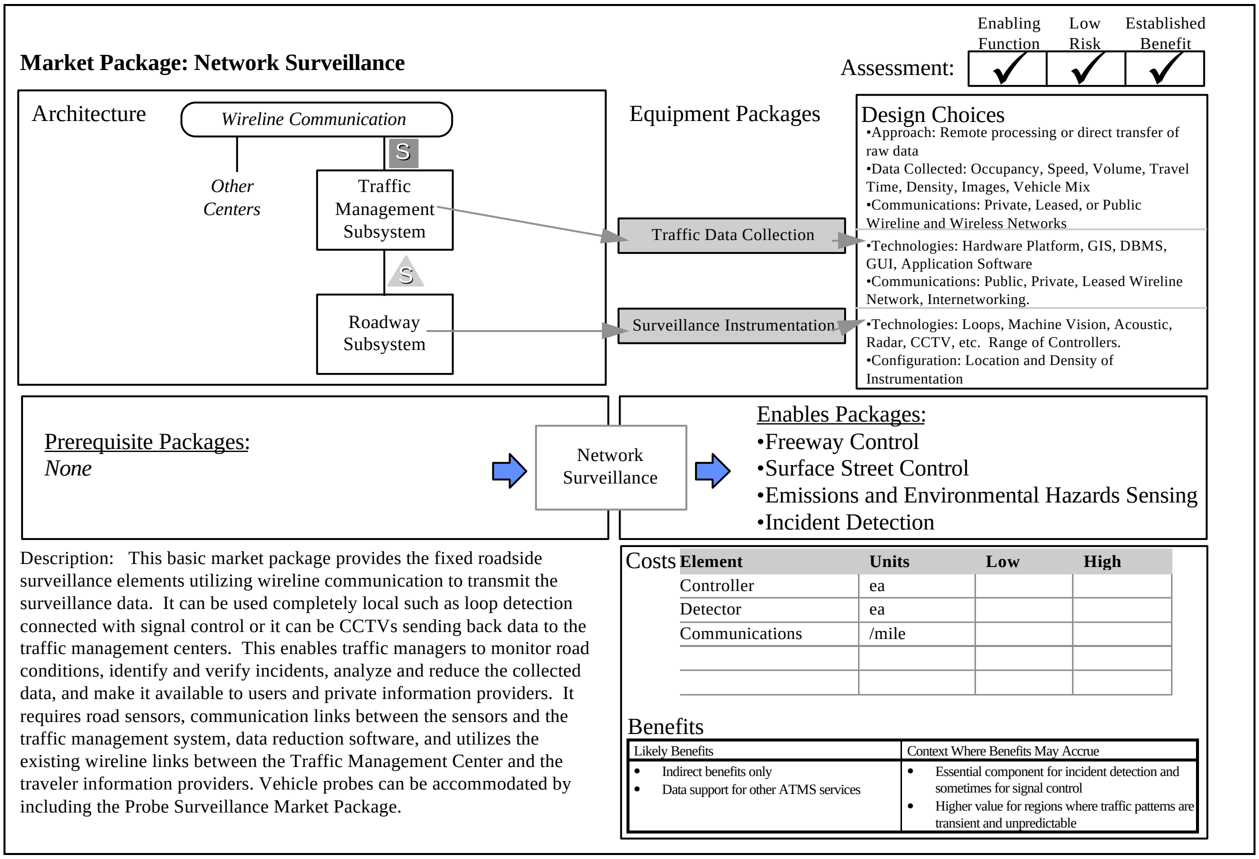
deployments by the DOT's modal administrations should be continued to support carefully scoped tests of initial architecture-compatible deployments (discussed further in 5.3).

Standardization should be the focus of targeted assessments. As standards are developed, DOT will need to develop strategies for achieving interoperability. Part of this strategy may entail funding state and local agencies for upgrades to new standards or restricting new funding to systems that conform with the standards. In addition, DOT may wish to provide funding to state and local agencies for the deployment of new systems with the objective of ensuring that early market packages are uniformly available throughout the country. Each of these options carries significant costs which must be justified through careful analysis.

5.2.3 Technical Guidance

System implementors will need clear guidance for implementing ITS systems so that they are consistent with the architecture. Answers to real-world questions regarding communications media, hardware and software procurement, integration options, performance requirements, and interface specifications must be readily available.

"Handbook" level documentation should be created to provide specific technical guidance for achieving, maintaining and exploiting the architecture. The handbooks would include an architecture overview and a method or procedure for utilizing the National Architecture and assessing consistency with the architecture as it matures into standards. Initially, these documents would include a refinement and consolidation of the executive summary, physical architecture, and implementation strategy products from the National Architecture program with some tailoring. Separate documents for diverse public sector and private sector audiences may be required that are focused on initial deployments pertinent architecture features. One approach would be to develop handbooks that are organized by market package or other deployment oriented categorization (such as type of organization) that could be augmented as standards become available and additional real-world experience is gained through operational tests and early deployments. Figure 5.2-1 is an example of the top-level guidance that could be assembled and presented to the implementor for each market package based almost exclusively on the material from sections 2 and 4 of this document.



Market Package: Network Surveillance

	Enabling Function	Low Risk	Established Benefit
Assessment:	✓	✓	✓

Design Choices
- Approach: Remote processing or direct transfer of raw data
- Data Collected: Occupancy, Speed, Volume, Travel Time, Density, Images, Vehicle Mix
- Communications: Private, Leased, or Public Wireline and Wireless Networks
- Technologies: Hardware Platform, GIS, DBMS, GUI, Application Software
- Communications: Public, Private, Leased Wireline Network, Internetworking.
- Technologies: Loops, Machine Vision, Acoustic, Radar, CCTV, etc. Range of Controllers.
- Configuration: Location and Density of Instrumentation

Prerequisite Packages:
None

Enables Packages:
- Freeway Control
- Surface Street Control
- Emissions and Environmental Hazards Sensing
- Incident Detection

Description: This basic market package provides the fixed roadside surveillance elements utilizing wireline communication to transmit the surveillance data. It can be used completely local such as loop detection connected with signal control or it can be CCTVs sending back data to the traffic management centers. This enables traffic managers to monitor road conditions, identify and verify incidents, analyze and reduce the collected data, and make it available to users and private information providers. It requires road sensors, communication links between the sensors and the traffic management system, data reduction software, and utilizes the existing wireline links between the Traffic Management Center and the traveler information providers. Vehicle probes can be accommodated by including the Probe Surveillance Market Package.

Costs

Element	Units	Low	High
Controller	ea		
Detector	ea		
Communications	/mile		

Benefits

Likely Benefits	Context Where Benefits May Accrue
• Indirect benefits only • Data support for other ATMS services	• Essential component for incident detection and sometimes for signal control • Higher value for regions where traffic patterns are transient and unpredictable

Figure 5.2-1: Sample Market Package Guidance Information Sheet

Existing transportation manuals, handbooks, and publications should also be refined to incorporate results of the architecture study. This effort should begin with an assessment of the significance and relevance of the architecture for existing documents. One of the many examples where the architecture is likely to be significant is FHWA's *Traffic Control Handbook*. The "documentation ripple" will be relatively small because the architecture overlays, rather than replaces, existing systems. However, at a minimum, it will be necessary for DOT to retain configuration control over a consolidated group of documents that are the basis for technical interpretations and assistance.

DOT should consider establishing a technical support service At a minimum, DOT will need to respond to inquiries from state and local officials, as well as private companies, regarding how the architecture and associated standards apply to their organizations. DOT will also likely receive inquiries as to whether specific ITS implementations conform to the architecture and its standards, or how ITS implementations could be modified to conform. As a "customer service," and to help ensure future interoperability, DOT should establish a technical support service that can quickly respond to questions over the phone and submitted by electronic mail or fax. A single national center, with dedicated employees, can likely serve this need better than relying on field representatives, whose duties may be split among several functions. This will also help to avoid confusing technical services with the more traditional role of project monitoring. Finally, a national technical support service could assume responsibility for producing handbooks, pamphlets, and a web site and developing other media for communicating with customers. The core expertise supporting the service would also be a key resource that could assist in developing U.S. positions for International Standards development.

5.2.4 Multi-Jurisdictional Implementation

Multi-jurisdictional coordination is essential to implementing a range of ITS market packages, including regional traffic control, multi-modal coordination, and electronic clearance. The architecture provides the technical framework to make such implementations quicker, more efficient and more effective. Specifically, the architecture promotes the use of open systems, which greatly reduces the need to replace existing systems and allows systems to be tailored to local needs. The architecture also provides an institutional framework for implementing ITS. This framework relies on inter-jurisdictional agreements regarding the deployment and operation of facilities, and on the development of an ITS planning process.

Planning processes for ITS should be adopted and promoted. Section 4 summarizes the ITS planning process contained in the *Interim Handbook on ITS Planning.* This process includes the steps of market package planning, regional architecture definition and strategic deployment planning. DOT should consider funding MPOs to develop regional ITS plans and, more specifically, regional ITS architectures. DOT should also consider requiring regional architectures as a precursor to funding deployment of multi-jurisdictional market packages.

Funding policies should promote efficient and effective partnerships Recent evidence indicates that successful partnerships have been formed in ITS, but that these partnerships are impeded by inefficient managerial processes. DOT funding guidelines should provide financial incentives to encourage the appropriate use of partnerships, so that multi-jurisdictional projects are implemented when coordination is cost-effective. Such projects should provide adequate managerial controls to ensure on-time and within-budget performance, including a designated lead agency to assume project management responsibility. Local and state agencies should exploit the architecture's flexibility in building from current systems, and should allow for coordination within distributed systems.

5.2.5 Individual Privacy

The traveling public has a strong expectation for privacy when using transportation systems, even though the courts have ruled that the same privacy safeguards that apply at home do not necessarily apply when using the public transportation system. As reviewed in Section 3, these concerns cover a range of actions, including concerns over surveillance, disclosure of personal information, and loss of privacy in commercial settings. Furthermore, the public expects that their rights to privacy will not be violated when traveling from state to state or city to city. For this reason, DOT has a responsibility to ensure that a maximum level of privacy is guaranteed when federal funding is used.

Guidance and agreements are needed to assure users of ITS that their desires for privacy will not be violated. Toward this end, DOT should develop rules and guidelines that protect identities of individuals, following from the privacy principles created by ITS America. Technical safeguards should be built into relevant subsystems such as billing. Supporting guidelines should also be developed for surveillance-oriented packages. ETTM systems can be deployed with cash or “digital” cash options. ATMS systems can use video systems at lower band resolutions (which can also be a cost saving). On the disclosure of personal information, traffic management centers can devise policies and procedures to ensure that ATIS information is treated in an acceptance manner, including policies for resale of data.

5.2.6 Proactive Procurement Reform

Some procurement practices at state, regional, and local levels create obstacles to ITS deployment, as revealed in *Nontechnical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems (US DOT, June, 1994)*. In general, many procurement laws and practices are not well suited to high-technology procurements.

Intellectual property reforms should be encouraged in state, regional, and local procurements. Recent ITS experience suggests that current federal policy is effective in attracting private sector participation by enabling retention of intellectual property. Similar policies should be encouraged, as necessary, to enhance private sector participation in cooperative high technology efforts.

Other undesirable constraints that adversely affect high technology procurements should also be considered for reform. As an example, low-bid requirements may be a barrier to innovative deployment of new technologies.

Partnerships with private industry should not be inhibited by anti-trust concerns. As reported in *IVHS and Antitrust: A Preliminary Assessment (FHWA, September, 1993)*: "[State and federal] governments are free to conduct research, develop and build intelligent highways, establish a unifying ITS system architecture, set standards and engage in host of activities without antitrust risk. Nor would private firms who lobbied the government, or cooperated with the governments, be liable"

5.2.7 Public/Private Sector User Fee Recovery

Deployments should be sustainable through user fees where possible. However, present policies may unduly restrict the public and private sector in recovering the cost of ITS services. In general, such restrictions should be removed.

Public agencies should be allowed to sell information to outside organizations, provided that privacy is protected. ATMS market packages are largely operated and maintained using public funds and rely on detailed information regarding traffic network performance to determine control strategies and perform long range planning. This same traffic information can be used to provide real-time route guidance and other value-added traveler information services. The architecture Cost Analysis and current experience indicate that traffic surveillance infrastructure, which enables this information collection, can be a significant public expenditure associated with ITS deployment. Strategies which defray infrastructure costs by charging a fee for information should not be precluded. In addition, deployment of shared surveillance resources should be pursued in order to minimize costs for both public and private sector participants.

<u>In general, sectors identified as performing a function should be responsible for funding</u> Sections 3.2 and 3.3 identify specific responsibilities. Furthermore, federal policies should not inhibit fee recovery when warranted.

5.2.8 Managing Liability

Liability is a major concern of the entire public sector, with the transportation sector being no exception. Indeed, each year state departments of transportation can face millions of dollars in liability claims. Consequently, the introduction of advanced technology systems can be hampered if perceived--rightly or wrongly--as exposing state departments of transportation and other local agencies to new levels of liability insurance.

<u>DOT should provide guidance to local agencies on how to implement ITS systems in a manner consistent with current liability policies</u>. Moreover, to the extent that such guidance can include state-of-the-art information on actual performance, decisions on deployment can be made with informed attention to the possible liability consequences. Liability guidance may become a function of the technical support center.

5.3 Strategic Investment in Research and Testing (R&T)

This section identifies strategic investments in research and testing (R&T) to facilitate early and sustainable deployments of ITS. The recommendations are based on several considerations: 1. Critical R&T topics closely associated with architecture and standards, 2. ITS services most promising for early deployment, and 3. Cross-cutting R&T topics that effect deployment and operation of multiple services, over both the near and far terms. The recommendations are *strategic* in the sense that specific projects are not defined; instead, the recommendations outline major topics and key considerations. The recommendations are not explicitly connected to the many ongoing R&T efforts sponsored by DOT, nor is a R&T program plan developed in detail. Instead, the recommendations are painted in rather broad strokes covering the principal dimensions of an effective ITS R&T program, with special attention to architectural features.

The organization of this section is as follows: Section 5.3.1 defines the traditional DOT stages of R&T. It describes how these stages apply specifically to learning about ITS and its associated architecture and standards. Section 5.3.2 outlines a set of consistent guidelines for R&T strategies and management policies for ITS. Next in section 5.3.3, some of the trends that can help establish R&T priorities are described. Finally, section 5.3.4 outlines and prioritizes important R&T topics.

5.3.1 R&T Motivations, Goals and Stages

An R&T program on the complex topic of ITS inevitably contains its own challenging complexities. This outline, therefore, necessarily covers only certain essential characteristics of an ITS R&T program, and does not attempt to define it in detail. In this subsection, the justifications of ITS R&T, its major goals, and its various stages are outlined. The primary purpose is to show how issues closely related to National Architecture affect some of the components of an appropriate R&T program.

The importance of the federal role in ITS R&T is closely associated with the *network system* nature of ITS. Because the benefits of public infrastructure and interface standards accrue not only to a single private firm (who in principle could finance the supporting R&T, but will not because it cannot retain the benefits for itself), but to entire populations of firms and to consumers, there is a role for the government in assisting and expediting R&T supporting infrastructure and standards. The critical role of standards is further amplified by current trends: local and regional authorities will have increasing authority and responsibility for infrastructure implementations, so that standards become a vital means of achieving the goals of interoperability, with associated payoffs in performance and cost. Standards can also make possible cooperative vehicle-infrastructure strategies (such as cooperative road markings) that can decrease costs and increase performance. Standards also become a critical means for enabling ITS to connect with rapidly evolving communication technologies, themselves developing in an increasingly decentralized and de-regulated environment.

The normal DOT stages of project funding from research and testing through deployment are listed in Table 5.3-1.

Table 5.3-1 R&T Stages

R&T Stage	Characteristics	ITS Examples
research and development	determination of feasibility of specific technologies and tools; highly to moderately unpredictable	feasibility of new algorithms for detection and control; new sensor development; improved simulation tools
testing	prototype testing; full system tests; moderate predictability	*Testbeds* for specific technologies; *Field Operational Tests*
demonstration	first full-scale operating example; high predictability	*Showcase Projects*
deployment support	post-testing support for actual deployments; direct application of relevant R&T results	*Early Deployment Planning; Deployment Support*

The second column of the table gives generic characteristics of the various R&T stages. The third column gives examples of ITS projects for each stage, together with identification of where current DOT ITS projects fit, by category (italicized terms in the last column refer to specific categories of DOT programs).

The characteristics of the various R&T stages in ITS also have implications for the management of R&T. This topic is taken up in the next section.

5.3.2 Establishing the Background for a R&T Program

Continual review of the state of the art and current trends must be part of the foundation of a R&T program. A variety of new and emerging technologies are available for supporting ITS services. These technologies include enhanced surveillance, communication, computation and information dissemination capabilities. Early deployments, especially in Transportation Management Centers (TMCs) have given positive indications of the most promising near-term systems. Over the next five years, there will be substantial expansion of TMCs, their capabilities will be upgraded, and their coordination with multiple agencies, modes and services greatly extended. These current trends should continue, including an expanded private sector role for delivery of ITS products and services (often making use of information and communication products developed for other markets) and a narrower government role focused on information collection, data management, and limited control (e.g., signals and schedules).

More specifically, R&T programs must recognize major trends that include:

(1) Private sector leadership in the development of personal navigation and transportation information devices, with no governmental control over the information being disseminated, and no governmental monitoring of individuals' vehicle locations. Government agencies, however, may be able to access such information on a voluntary basis.

(2) Installation of computer systems that enable vastly improved access to information, as well as an ability for automatically reporting on system performance.

(3) Direct communication lines and established protocols that improve the coordination of transportation services among governmental agencies.

(4) Expanded capabilities of transit operators to monitor vehicle locations, along with a capability for real-time scheduling and routing.

(5) Expanded use of cellular phones, enabling individual travelers to report highway incidents and to access information services.

(6) Widespread use of surveillance systems based on new technologies, providing vastly improved capabilities for detecting and assessing incidents. Technologies include, but are not limited to, vision-based systems and probe vehicles.

(7) A greater range of roadway-mounted sensor types for monitoring hazardous conditions, and possibly emission violations.

(8) Wireless communication infrastructure to support dynamic route guidance systems, likely provided by the private sector.

(9) Greatly increased capacity for land-line communication.

(10) Widespread use of changeable message signs for communicating traveler advisories, along with completely open access to transportation information through personal computers, telephones, and cable television systems.

(11) Increased importance of integrated transportation system assessments, planning and design.

(12) Commercially developed, stand-alone AVCS products will appear on the market, e.g. adaptive cruise control and collision warning.

(13) Within five years, the National Architecture will become well established, and this architecture will provide a framework for nation-wide deployments .

To effectively acknowledge these trends, a R&T program must have a systematic procedure for tracking the performance of new technologies and operational practices , and for understanding changing and emerging needs and markets. The program needs to be able to discontinue directions proven to be ineffective and quickly examine promising alternatives.

5.3.3 R&T Priorities

Within the above guidelines, we identify the following as important R&T topics. Topics marked with a * have the highest priority, either because they are closely associated with important architectural or standards issues, because they are needed for likely early deployments or because they are associated with a critical long-term need, often cutting across multiple services. Both research and testing will tend to be components of each topic. Testing is addressed explicitly in the following section. Finally, Section 5.3.6 presents an overview of R&T topics, and summarizes the characteristics of each topic.

***National Architecture for State and Local Deployments**. Investigate how the National Architecture can be best applied to develop "regional architectures" that satisfy state and local needs and constraints, while achieving the major goals of the National Architecture. Determine how such regional architectures can help improve *coordination*: among governmental agencies, among different transportation modes, between government and the private sector, and between government and individual travelers. Identify critical connections among institutions, technology and operations, and how coordination among these entities can improve performance. It is particularly important to identify the role of standards in the facilitation of inter-agency, multifunction coordination and in the acceleration of deployments. This R&T can help guide the standards development process by identifying how specific standards facilitate coordination and deployment.

***Data Collection and Storage for R&T, Evaluation, Planning, and Operation**
ITS makes possible the acquisition of huge quantities of valuable, real transportation data. A better understanding is needed of how to collect, manage, retrieve and apply this data on a project, regional and national level, in a wide variety of applications. Relevant data include traffic flow, travel demand, trip generation, market demand for travel and traffic information, and technology and system performance. Consideration should be given to providing incentives for appropriate data collection in projects that use federal funds. Establish an automated, nation-wide transportation reporting system. It will be critical to promote standards for data types, quality and formats, to insure maximum communication ease and relevance. (See the relevant Market Package, ITS Planning (ITS1).)

State-of-the-art data base approaches should be used to promote efficiency and ease of data exchange and use. For example, object-oriented databases are capable of integrating key model elements: traffic simulation packages, data sets, and computational tools. In turn, this kind of approach can efficiently guide and facilitate new software development.

Because of the intense needs for data in ITS systems analysis and design, and the requirements for efficiently sharing large quantities of information among many users and applications, we expect such smart databases to have high value in the future, both for researchers as well as implementors. An important question is how best to apply these technologies for the most cost-effective storage and retrieval of data for specific transportation management, planning and research purposes.

At the operational level, we need to investigate how information (and appropriately designed management processes) can be used to support and motivate performance improvements in the delivery of ITS services.

***Data Acquisition Technologies and Systems**
Within the framework of the National Architecture, investigate the data required for control, performance monitoring and information dissemination purposes. Investigate alternative means for acquiring data, processing data and communicating data from remote sites. Data acquisition methods will include both direct surveillance (via loops, video, other imaging/detection/identification/tracking techniques) and indirect means, such as vehicle probes. Analysis must not only include the technical performance of sensor technologies, but the system aspects of communication requirements, standards compatibility and the impact of sensor systems on overall system performance. Models should be developed that support cost/benefit trade-offs between system performance and data acquisition costs. Testbeds and Field Operational Tests will play an important role in confirming the most cost-effective mixes of technologies for specific purposes.

***Traffic and Travel Simulation for ITS**

Although much effort has been expended on developing traffic models and simulations over the past 30 years, currently available computer simulations are unable to simulate many promising ITS functions. This is an area where national attention is vital to avoid duplication of effort, and to organize critical masses of effort to attack a difficult and challenging problem.

With regard to system architecture, it is important to develop simulation tools that capture the effects of specific information flows and uses, as well as corresponding decisions (management system as well individual traveler). Of particular architectural interest are: 1. simulations that capture adequately the effects of coordination across services, regions and modes, as well as traveler behavior in the context of ITS services, and 2. identification of appropriate interfaces to and from on-line simulations (see "Short-Term Forecasting" below), to enable simulations to be linked efficiently into operations.

Standard approaches are needed to evaluate and compare models with respect to numerous criteria: how they model traffic dynamics, and how they represent networks, intersection signal control, multiple driver classes, route selection approaches, vehicle types, incidents, special devices, and demand management. Requirements for input data, hardware, memory and computational run-time must also be provided. We must be able to evaluate models for their validity, to determine whether the outputs are consistent with “known” or anticipated results, and if the model outputs are unduly sensitive to any input parameters. Such an investigation, if performed with standard criteria and base data sets, will be helpful to the whole community in improving and establishing solid R&T and evaluation tools.

Useful simulations will have to be able to assess a range of meaningful system and user performance measures, e.g. travel time distribution, mean and variance. One particular measure that has received increasing attention with the advent of ITS, but as yet remains most difficult to evaluate, is "mobility". Mobility represents the benefits to individual travelers of increased knowledge of travel options and conditions (through greater trip and associated activity utility); sufficiently rich models to be able to estimate mobility benefits would be useful in settling debates about the importance of this benefit.

*Short-Term Forecasting

This need is an important near-term aspect of general traffic simulation requirements. Statistical methods are needed for real-time estimation of system performance as well as short-term forecasting of traffic. These methods would be used within TMCs to: (1) optimize the selection of control strategies, and (2) develop dynamic travel time estimates on an origin/destination and link basis. The travel time estimates could be further used within route guidance systems to identify shortest travel time paths in real time. Travel time estimates would also be incorporated within the TMCs' performance monitoring systems, to track average travel times on a day-to-day basis. An important topic is the integration of simulations into TMC architectures.

*Transportation Management Center (TMC) Coordination

A significant amplification of benefits and greater economies may occur from combining and coordinating functions across related services and across different modes and adjacent regions. Transportation Management Centers (TMCs) are becoming the central focal points for monitoring and managing transportation systems, and they bring the possibility of such improved coordination and resulting benefits.

A number of regions have made great strides in developing TMCs, and in coordinating certain functions such as traffic management and law enforcement. Despite these accomplishments, however, TMCs have yet to achieve their full potential for becoming the nerve centers of a large array of traffic management functions. Effort is needed to determine the best way to integrate a greater scope of advanced ITS functions into TMC operations, to extend them to the coordination of more functions, modes and agencies, and to support them with appropriate mixtures of computer automation and operator involvement. Key architectural issues include how to select a regional architecture that best fits local needs, local institutional conditions and existing and projected communications infrastructure; how to assign responsibilities and authority in specific multi-agency, multi-service contexts; and how best to integrate technology and management structure, paying particular attention to how to maximize incentives for improving efficiencies and service. Another key question involves how best to incorporate the private sector, either as a direct and independent service provider, as a partner, or as a contractor to a public agency.

***Institutional and Organizational Phenomena**
Of the many important ITS institutional issues the ones of most direct concern to architecture are the following: 1) What are the institutional barriers to inter-regional, intermodal and inter-functional coordination, and what are the best approaches for overcoming them? 2) How do these barriers interact with various technological, operational and organizational options for their amelioration? 3) How do we best integrate the private sector into the delivery of services?

***Benefits Evaluation**
Many of the topics in this section either directly or indirectly contribute to the evaluation of benefits. However, the problems of usefully evaluating benefits will remain daunting unless more effort is put into framing benefits evaluations in ways that decision makers will find compelling and useful. Present evaluations are often unused, for a variety of reasons: unsound methodology, unjustified or indeterminate assumptions and parameter specification, unvalidated (or clearly inaccurate) simulations, lack of valid estimates of uncertainty in benefit estimations, and differences between the test or simulation conditions and the conditions of interest to a potential implementor. Much of the R&T called out here will address these problems, but more is needed, along the lines of the establishment of "good benefits-evaluation standards and practices" that address all the above problems, and encourage researchers and testers to pay attention systematically to these issues.

***Planning Tools**
To a prospective governmental implementor, ITS deployments often appear complex, expensive and risky. Relevant, smart data bases and appropriate decision support systems would facilitate the planning and execution of such projects. These tools should be able to support groups of agents working together, using disparate sources of data to evaluate alternative ITS (and other transportation) deployments and enable them to come to consensus decisions. These tools must also fit the ITS planning process described in section 4.1. Finally, tools should be consistent with

standards developed for the ITS Planning Market Package (ITS1), and should treat benefits, costs and uncertainties in a methodologically sound way that permits information from various sources to properly evaluated and effectively integrated. A specific example of such a tool is a rough-order-magnitude cost analysis tool that enables rapid assessment of costs associated with prospective ITS deployments. Such a tool may be developed from the basic cost analysis performed to support the National Architecture and Intelligent Transportation Infrastructure initiatives. (See "Data Collection" and "Benefits Evaluation" for discussion of important types and sources of data.)

Of particular interest are tools that permit planning and operating agencies to make effective investment decisions based on available benefit and cost information (see above topic), together with a realistic assessment of uncertainties. Specifically, it is important that these tools permit local agencies to make informed decisions on the adoption of standards. In this regard, more research is required to make explicit all the cost-benefit tradeoffs for a local agency in standards adoption.

Geographical Information Systems

Ongoing work on developing standard methods for representing geographical information should be completed as soon as possible. Because of the many ITS services that use such information, standard representation methods will have a large and positive impact.

AVCS and AHS

Although these topics have not received primary emphasis in this study, these applications raise their own special communication, architectural and standards issues that will require increasing attention in the future. In this context it is particularly important to understand how best these systems can be deployed in a progressive manner, and what the architectural and standards implications are of various possible progressive deployment strategies.

Technology

Table 2.5-3 identified critical needs for technology development, together with likely public-private funding responsibilities, and relevant time frames for execution. Technologies cited for primary public investment were:

- vehicle status sensors for emissions, passenger counts and safety
- driver monitoring sensors
- algorithms--application dependent

In addition, a number of areas were called out for private research funding, and some for primarily private funding, to be augmented by public funds. All of the topics in the latter category (obstacle ranging sensors, lane tracking sensors, vehicle-vehicle communication and vehicle control), come under the responsibility of the AHS Program, and are topics under intense current review there. In addition, vehicle safety status sensors (and systems for monitoring and managing system safety state), cited above for public funding, have important AHS applications and are receiving significant attention there.

5.3.4 Testbeds and FOTs

To ensure cost-effective investments in ITS, it is important to continue programs for testing technologies and systems prior to their deployment. Many local implementors will not make investments until they have seen ITS benefits revealed in actual tests. Testing may take place within designated testbeds (either in the field or in the laboratory) or through field operational test (FOTs). Testing functions can also be assumed by modeling and simulation, as cited in earlier R&T topics.

Essential features of *testbeds* include:

- dedicated installations for data collection, communication and processing

- ability to replicate desired operating conditions

- flexibility to test a range of technologies and systems

Good examples of current ITS testbed activities include the National Advanced Driving Simulator and a number of sites which have been set up to test and evaluate new traffic surveillance products and technologies.

In contrast, *field operational tests* are targeted at one-time evaluations of specific technologies or systems. Their most salient feature is the ability to test under complete real-world conditions that could not be attained normally in a testbed. (Clearly, there are also "testbeds" that are set up in the real, operating world--providing the ability to test with some of the convenience and efficiencies of regular testbeds combined with the real-world conditions of an FOT.)

In general, testing is used to:

- measure the functional performance of a technology or system, e.g. whether they achieve specifications and requirements

- determine the usability and acceptability of particular system features from the perspective of operators or travelers

(While the above goals can often be achieved in testbeds, the following usually require an FOT (or combined testbed-FOT) for their achievement.)

- evaluate the ability of organizations to implement, operate and manage a technology or system, from institutional and organizational perspectives.

• assess the effect of a technology on overall system performance, including travel time safety, congestion and pollution.

• analyze the overall cost-effectiveness of a system.

• determine the ability of all pieces and levels of a system to operate smoothly together when finally integrated in the real world.

Testing under government sponsorship may be desirable when any of the following conditions are met:

• technologies or systems have successfully passed through the research and development stage, under federal funding (having previously passed the requirements for federal funding of research), they remain promising but there is still uncertainty regarding their performance under actual use. This test also applies to technologies or systems that have private or public-private origins, if the potential investment is a public one, and tests are needed to resolve performance uncertainties.

• a private company wants its technology publicly evaluated. The company would normally pay for the tests, if the technology is proprietary.

• a promising technology carries potential risks and hazards to the public that need to be assessed prior to deployment to ensure adequate public safety.

• a technology or system requires public support (funding, infrastructure, operation, information), but has never been employed in a particular application or system architecture.

In all cases, the expected long-term benefit from a successful technology must substantially outweigh the costs directly associated with the test, along with the possible cost of delaying the technology's implementation.

It is also desirable for the government sponsoring agencies to develop a capability for rapidly screening technologies through simulations and rapid testing, and to expose only a limited number of technologies to rigorous field test (those technologies that are neither obviously cost-effective nor obviously cost-ineffective, and which have large *potential* cost-effectiveness). Because ITS technologies are developing rapidly, most tests should be designed and completed within a short time (normally one year). This rapidity requires permanent testbed facilities along with the capability to rapidly execute contracts for testing.

5.3.4.1 Testing and Systems Architecture

In hindsight, early FOTs have turned out to be less predictable than originally believed. A partial explanation is found in the common character of ITS tests. Most FOTs, even the simpler ones, are new *system* deployments, involving: 1. interconnections of new (or newly adapted) technologies, by new operators, in new contexts and applications, with new users, and 2. requirements for cooperation in planning, deployment and operation of new agents in new partnerships. Even when all the pieces have been tested and proven in isolation, there are typically enough new connections and coordination required that new, *system* risks arise. In the evolution from research to deployment of a set of ITS technologies, FOTs often confront for the first time the architectural issues of interfaces and coordination, and this accounts for much of their challenge. As the architecture and associated standards are adopted, many of the problems and risks encountered by these FOTs will be ameliorated, but not entirely eliminated.

Future testing should build upon the results of DOT's ongoing FOT program. Tests should be planned through a formal decision process established for managing R&T in a coordinated fashion over time. It will be important to clearly identify costs, benefits and uncertainties, and the users of the information anticipated from the tests. Finally, the information should be put into usable forms and widely disseminated (see especially the Data Collection R&T topic above).

A testing program relevant to the National Architecture should be developed consistent with the following guiding principles:

1. FOT evaluations (including those of ongoing tests) should systematically report on relevant architectural issues, e.g. the effectiveness of standards as employed in the test, or recommendations of standards arising from the test experience. A potentially useful related project would be to cull past and on-going FOT efforts for experience and advice on standards issues, and to structure and classify this information in a way that would be most useful to standard-setting efforts, as well as to other operators and implementors.

2. Future FOTs should include tests of the integration of telecommunication technologies with specific applications and users. Evaluation goals should be the cost-effectiveness of the integrated system, its "marketability" and usability. Tests should be defined carefully by selecting the most promising combinations of telecommunications technology and applications, and fielding them in the most promising and representative institutional and operational settings. The main object of these operational tests should *not* be telecommunications technologies themselves, as they are largely well understood and technically adequate for a range of applications--see Sec. 7, Communication Technology Assessment, of the "National ITS Communication" document. Rather, the key questions are *how communications and applications fit together into an effective partnership with transportation agencies, and how this combination can deliver desired, cost-effective services to users who are willing to pay for them.*

The design of such tests involves considerations of application priority, technology promise and fit, and effective partnership structure. Because of this complexity, it is not possible or appropriate to design or recommend specific tests here. Instead we have recommended important underlying principles and goals that such tests should satisfy if they are to support the implementation of the National Architecture

5.3.5 R&T Overview

Table 5.3-2 lists all the research and test recommendations and identifies the potential components of research and testing each addresses. Cross-cutting indicates that the research topic spans multiple market packages. This table builds on table 5.3-1 which showed possible connections between the column stages shown here and the various phases of DOT R&T programs.

Table 5.3-2 Properties of Recommended R&T Topics

Topic	**Research**	**Testing**	**Benefit Evaluation**	**Tools Development**	**Cross Cutting**
*National Architecture	X	X	X		X
*Data Collection and Storage		X	X	X	X
*Data Acquisition	X	X	X	X	X
*Traffic & Travel Simulation	X	X	X	X	X
*Short-term Forecasting		X	X	X	X
*Transportation Management Centers		X	X		X
*Institutional & Organizational	X		X		X
*Benefits Evaluation	X	X	X	X	X
Planning Tools		X	X	X	X
GIS	X	X	X	X	X
AVCS & AHS	X	X	X	X	
Technology	X	X	X	X	X
Testbeds & FOTs		X	X		X

Although the National Architecture Program represents a significant step in the journey towards integrated ITS solutions, many challenges remain. The investment recommendations made in this section address many of these challenges. The Implementation Strategy is aimed to assist localities in devising various deployment plans to customize the architecture to their own circumstances and needs. Nonetheless, there is a crosscutting need to understand the key uncertainties--technical and non-technical--as regions move to higher levels of ITS integration. The R&T recommendations address these uncertainties by outlining a range of research areas that address integration challenges, ranging from integration of data (technical integration) to integration of institutions (non-technical integration).

A. Detailed Market Package Definitions

To provide visibility into the deployment options that must be considered by the ITS implementor, a set of *market packages* have been defined. The market packages provide an accessible, service oriented perspective to the national architecture. They address the specific service requirements of traffic managers, transit operators, travelers, and other ITS stakeholders. To achieve an implementation orientation, the market packages were defined with enough granularity to support specific benefits analysis and clear ties to transportation problems. Some of the user services are too broadly defined to allow this sort of evaluation. The complete set of market packages are identified in Table A-1. In order to more accurately specify market packages in tables, each is given an abbreviation indicating the general class of stakeholder and an index (e.g., ATMS01 is a market package primarily of interest to transportation managers).

Table A-1: Market Packages Summary

Market Package	Market Package Name
ATMS01	Network Surveillance
ATMS02	Probe Surveillance
ATMS03	Surface Street Control
ATMS04	Freeway Control
ATMS05	HOV Lane Management
ATMS06	Traffic Information Dissemination
ATMS07	Regional Traffic Control
ATMS08	Incident Management System
ATMS09	Traffic Prediction and Demand Management
ATMS10	Electronic Toll Collection
ATMS11	Emissions Monitoring and Management
ATMS12	Virtual TMC and Smart Probe Data
ATMS13	Standard Railroad Grade Crossing
ATMS14	Advanced Railroad Grade Crossing
ATMS15	Railroad Operations Coordination
ATMS16	Parking Facility Management
ATMS17	Reversible Lane Management
ATMS18	Road Weather Information System
APTS1	Transit Vehicle Tracking
APTS2	Transit Fixed-Route Operations
APTS3	Demand Response Transit Operations
APTS4	Transit Passenger and Fare Management
APTS5	Transit Security
APTS6	Transit Maintenance
APTS7	Multi-modal Coordination
APTS8	Transit Traveler Information
ATIS1	Broadcast Traveler Information

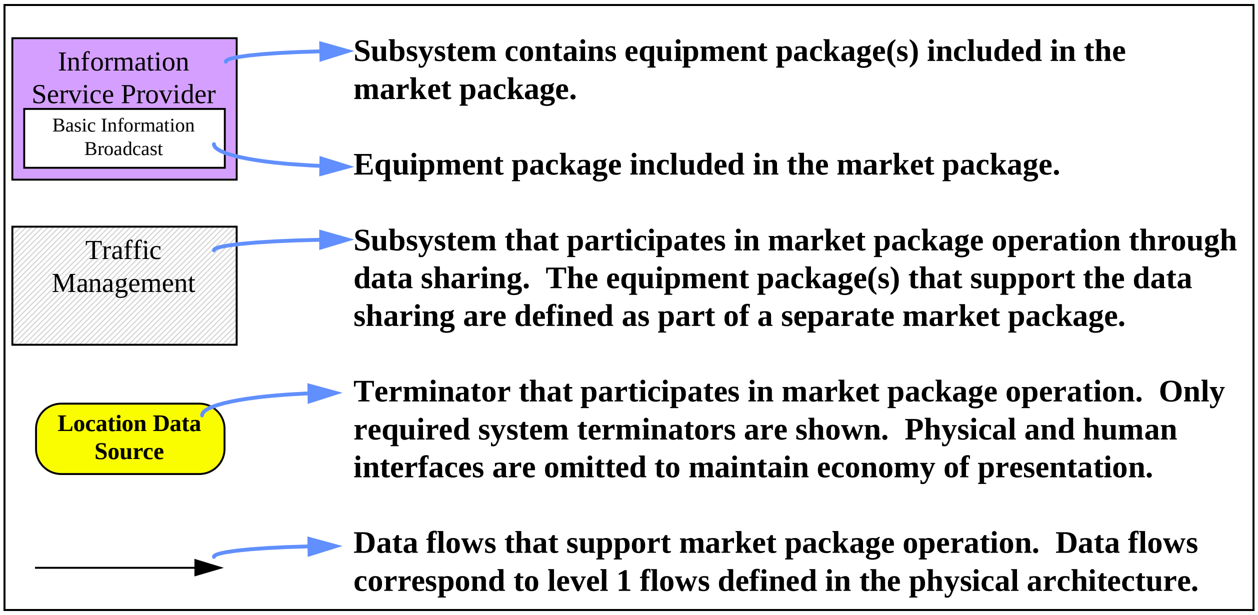
Market Package	Market Package Name
ATIS2	Interactive Traveler Information
ATIS3	Autonomous Route Guidance
ATIS4	Dynamic Route Guidance
ATIS5	ISP Based Route Guidance
ATIS6	Integrated Transportation Management/Route Guidance
ATIS7	Yellow Pages and Reservation
ATIS8	Dynamic Ridesharing
ATIS9	In Vehicle Signing
AVSS01	Vehicle Safety Monitoring
AVSS02	Driver Safety Monitoring
AVSS03	Longitudinal Safety Warning
AVSS04	Lateral Safety Warning
AVSS05	Intersection Safety Warning
AVSS06	Pre-Crash Restraint Deployment
AVSS07	Driver Visibility Improvement
AVSS08	Advanced Vehicle Longitudinal Control
AVSS09	Advanced Vehicle Lateral Control
AVSS10	Intersection Collision Avoidance
AVSS11	Automated Highway System
CVO01	Fleet Administration
CVO02	Freight Administration
CVO03	Electronic Clearance
CVO04	CV Administrative Processes
CVO05	International Border Electronic Clearance
CVO06	Weigh-In-Motion
CVO07	Roadside CVO Safety
CVO08	On-board CVO Safety
CVO09	CVO Fleet Maintenance
CVO10	HAZMAT Management
EM1	Emergency Response
EM2	Emergency Routing
EM3	Mayday Support
ITS1	ITS Planning

The deployment oriented market packages are traceable to the interface-oriented architecture definition. Once a particular market package is selected for implementation, the required subsystems, equipment packages, and interface requirements are readily identified due to this traceability. This approach allows the implementor (and this Implementation Strategy) to first consider service needs and later concentrate on those pieces of the architecture necessary to provide the selected service.

It is important to note that the market packages are illustrative rather than prescriptive. The actual implementation variations that are possible across the country are myriad and cannot be enumerated through a finite set of packages. The market packages are tools that allow this Implementation Strategy to discuss incremental deployment of ITS services in a manner that is relevant to the underlying architecture definition.

The remainder of this appendix defines each of the market packages in more detail. A description of the service offered by each market package is coupled with a graphic that identifies how the architecture framework supports the market package. Where several major implementation options are supported by the market package, these are also identified and differentiated in the descriptions.

Figure A-1 provides a legend to assist in interpretation of the market package diagrams. In general, only the most salient elements from the architecture definition (e.g., directly involved subsystems, system terminators, and the highest level data flows) are depicted in each graphic to ensure clarity.



Subsystem contains equipment package(s) included in the market package.

Equipment package included in the market package.

Subsystem that participates in market package operation through data sharing. The equipment package(s) that support the data sharing are defined as part of a separate market package.

Terminator that participates in market package operation. Only required system terminators are shown. Physical and human interfaces are omitted to maintain economy of presentation.

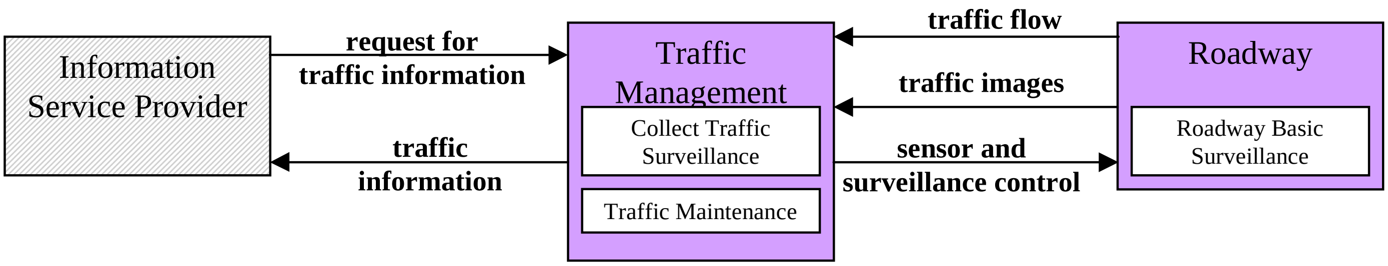
Data flows that support market package operation. Data flows correspond to level 1 flows defined in the physical architecture.

Figure A-1: Market Package Diagram Elements

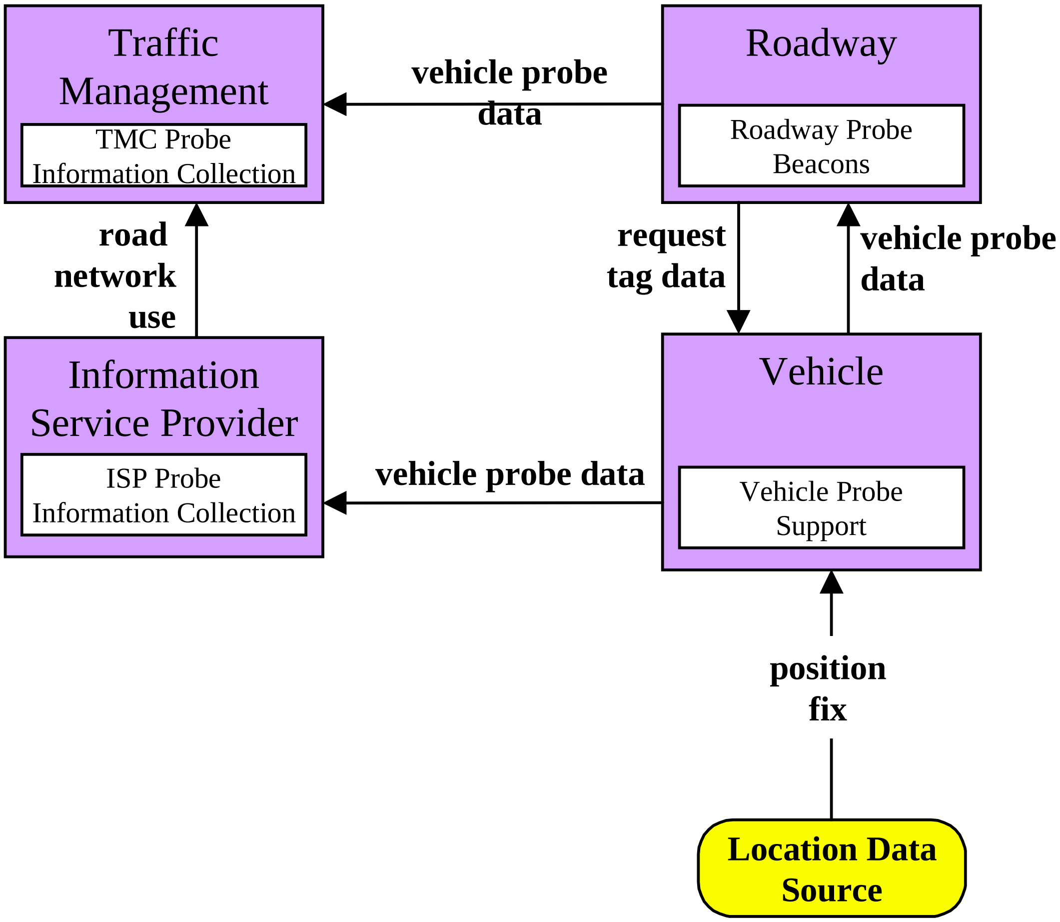
A.1 Traffic Management Market Packages

Network Surveillance (ATMS1)

This market package includes traffic detectors, environmental sensors, other surveillance equipment, the supporting field equipment, and wireline communications to transmit the collected data back to the Traffic Management Subsystem. The derived data can be used locally such as when traffic detectors are connected directly to a signal control system or remotely (e.g., when a CCTV system sends data back to the Traffic Management Subsystem). The data generated by this market package enables traffic managers to monitor traffic and road conditions, identify and verify incidents, detect faults in indicator operations, and collect census data for traffic strategy development and long range planning. The collected data can also be analyzed and made available to users and the Information Service Provider Subsystem.

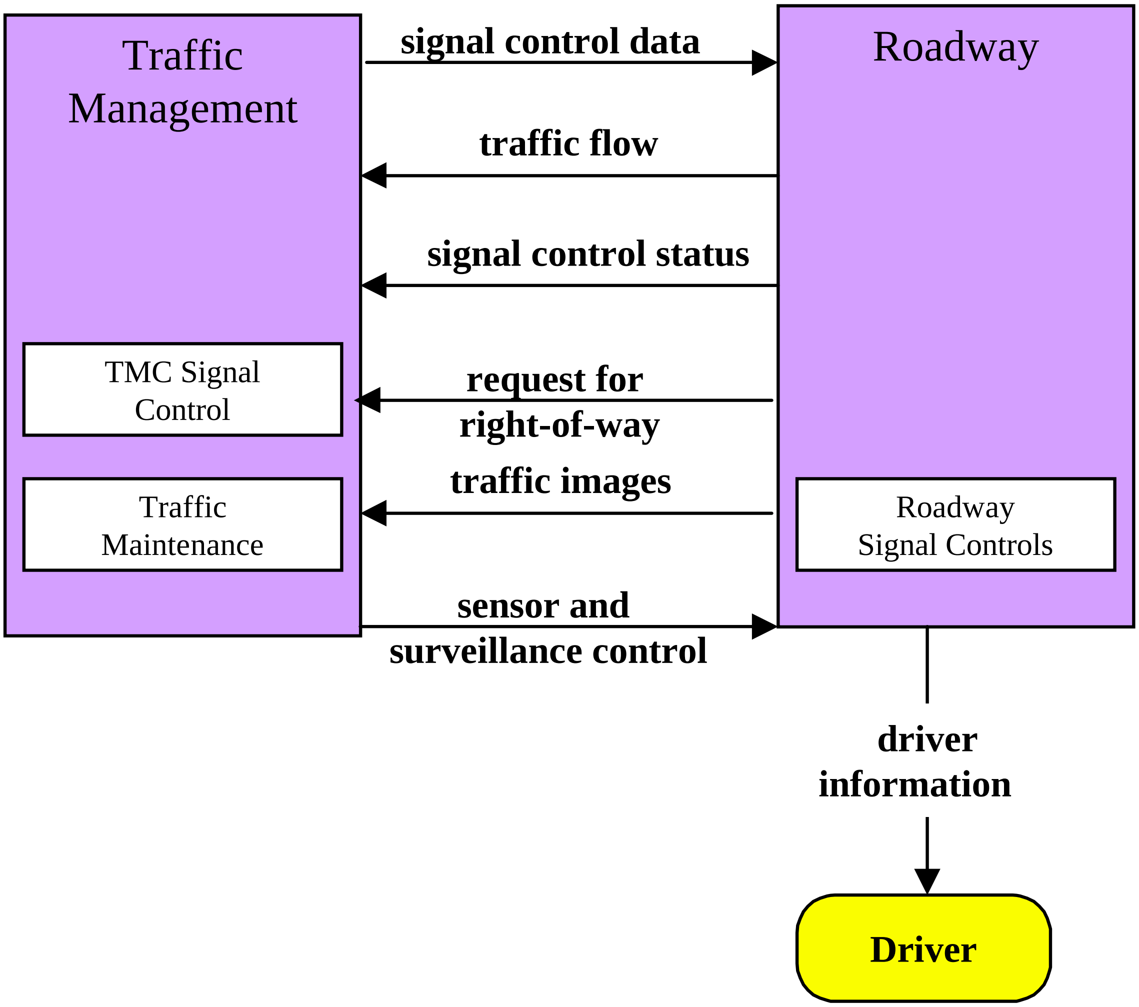


Probe Surveillance (ATMS2)
This market package provides an alternative approach for surveillance of the roadway network. Two general implementation paths are supported by this market package: 1) wide-area wireless communications between the vehicle and Information Service Provider is used to communicate current vehicle location and status, and 2) dedicated short range communications between the vehicle and roadside is used to provide equivalent information back to the Traffic Management Subsystem. The first approach leverages wide area communications equipment that may already be in the vehicle to support personal safety and advanced traveler information services. The second approach utilizes vehicle equipment that supports toll collection, in-vehicle signing, and other short range communications applications identified within the architecture. The market package enables traffic managers to monitor road conditions, identify incidents, analyze and reduce the collected data, and make it available to users and private information providers. It requires one of the communications options identified above, roadside beacons and wireline communications for the short range communications option, data reduction software, and utilizes wireline links between the Traffic Management Subsystem and Information Service Provider Subsystem to share the collected information. Both "Opt out" and "Opt in" strategies are available to ensure the user has the ability to turn off the probe functions to ensure individual privacy. Due to the large volume of data collected by probes, data reduction techniques are required in this market package, which include the ability to identify and filter out-of-bounds or extreme data reports.



Surface Street Control (ATMS3)

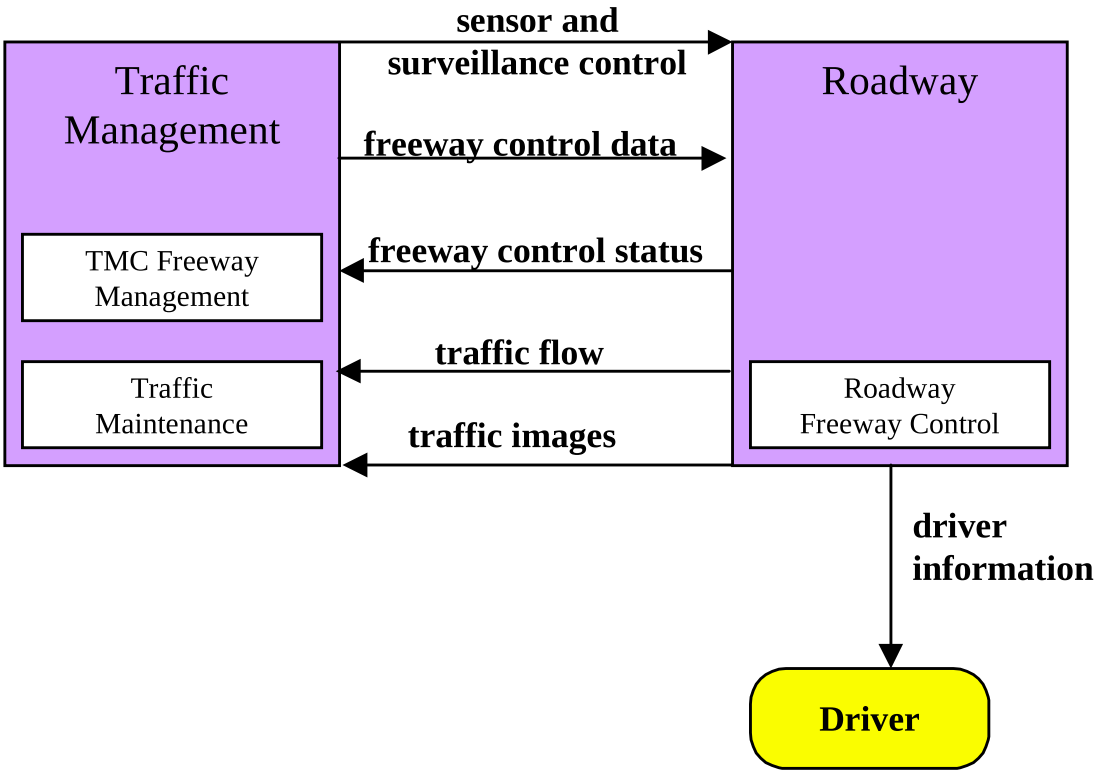
This market package provides the central control and monitoring equipment, communication links, and the signal control equipment that support local surface street control and/or arterial traffic management. A range of traffic signal control systems are represented by this market package ranging from static pre-timed control systems to fully traffic responsive systems that dynamically adjust control plans and strategies based on current traffic conditions and priority requests. Additionally, general advisory and traffic control information can be provided to the driver while en-route. This market package is generally an intra-jurisdictional package that does not rely on real-time communications between separate control systems to achieve area-wide traffic signal coordination. Systems that achieve coordination across jurisdictions by using a common time base or other strategies that do not require real time coordination would be represented by this package. This market package is consistent with typical urban traffic signal control systems.



Freeway Control (ATMS4)

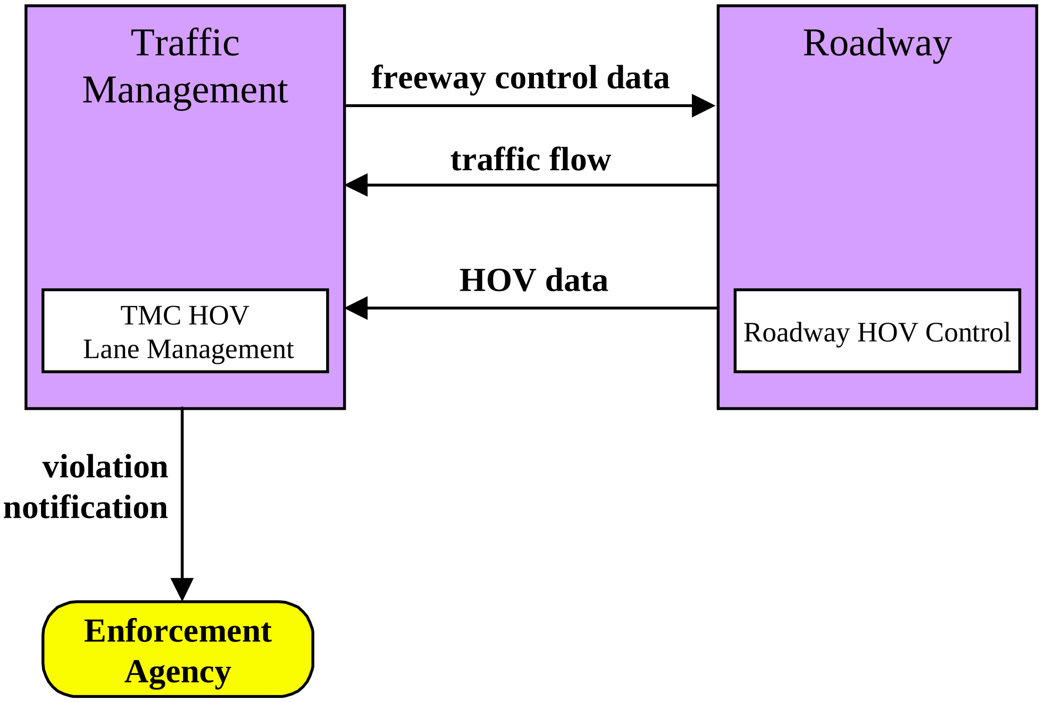
This market package provides the communications and roadside equipment to support ramp control, lane controls, and interchange control for freeways. Coordination and integration of ramp meters are included as part of this market package. This package is consistent with typical urban traffic freeway control systems. This package incorporates the instrumentation included in the Network Surveillance Market Package to support freeway monitoring and adaptive strategies as an option.

This market package also includes the capability to utilize surveillance information for detection of incidents. Typically, the processing would be performed at a traffic management center; however, developments might allow for point detection with roadway equipment. For example, a CCTV might include the capability to detect an incident based upon image changes. Additionally, this market package allows general advisory and traffic control information to be provided to the driver while en-route.



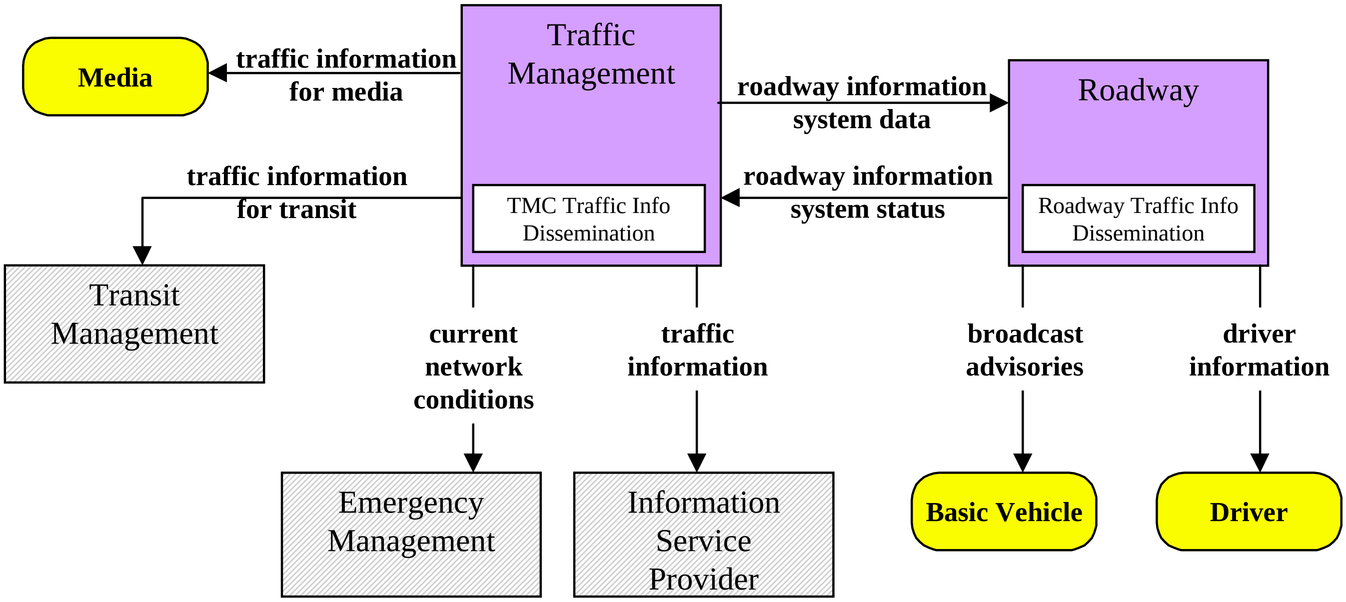
HOV Lane Management (ATMS5)

This market package manages HOV lanes by coordinating freeway ramp meters and connector signals with HOV lane usage signals. Preferential treatment is given to HOV lanes using special bypasses, reserved lanes, and exclusive rights-of-way that may vary by time of day. Vehicle occupancy detectors may be installed to verify HOV compliance and to notify enforcement agencies of violations.



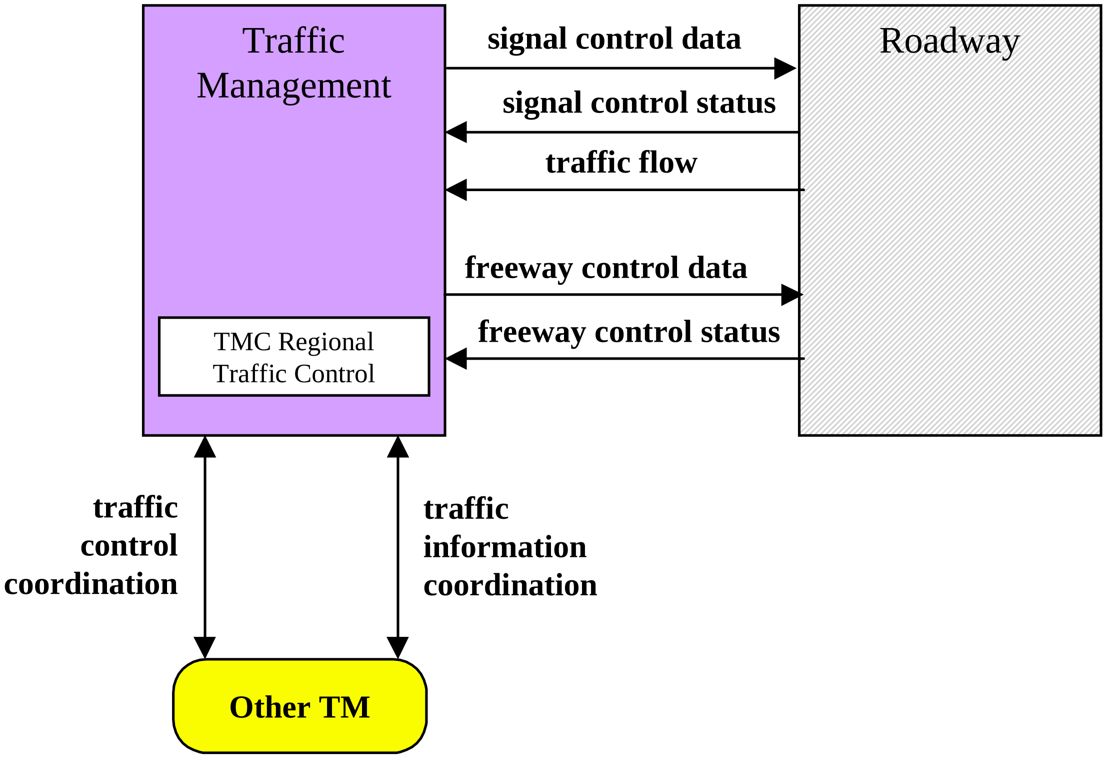
Traffic Information Dissemination (ATMS6)

This market package allows traffic information to be disseminated to drivers and vehicles using roadway equipment such as dynamic message signs or highway advisory radio. This package provides a tool that can be used to notify drivers of incidents; careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information. This package also covers the equipment and interfaces that provide traffic information from a traffic management center to the media (for instance via a direct tie-in between a traffic management center and radio or television station computer systems), transit management center, emergency management center, and information service provider.



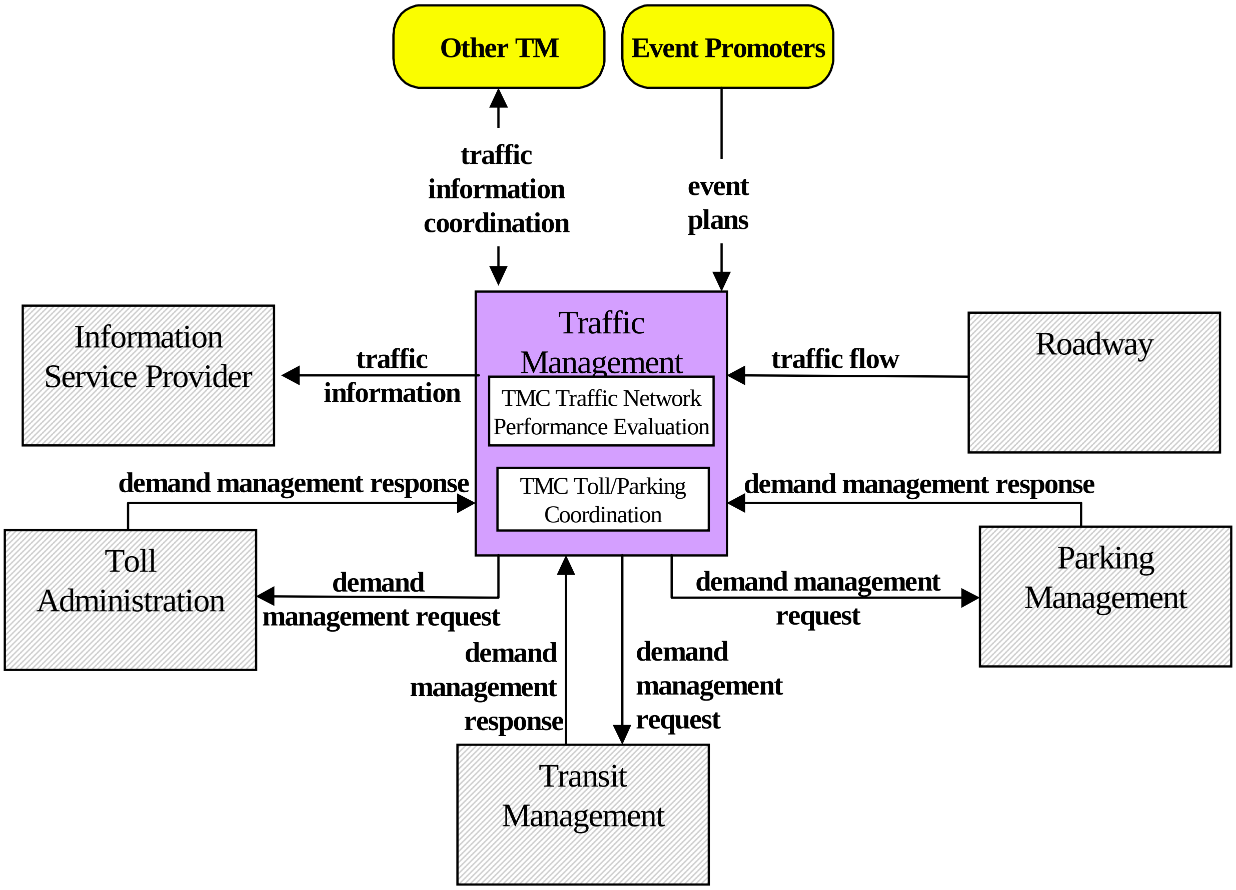
Regional Traffic Control (ATMS7)

This market package advances the Surface Street Control and Freeway Control Market Packages by adding the communications links and integrated control strategies that enable integrated interjurisdictional traffic control. This market package provides for the sharing of traffic information and control among traffic management centers to support a regional control strategy. The nature of optimization and extent of information and control sharing is determined through working arrangements between jurisdictions. This package relies principally on roadside instrumentation supported by the Surface Street Control and Freeway Control Market Packages and adds hardware, software, and wireline communications capabilities to implement traffic management strategies which are coordinated between allied traffic management centers. Several levels of coordination are supported from sharing of information through sharing of control between traffic management centers.



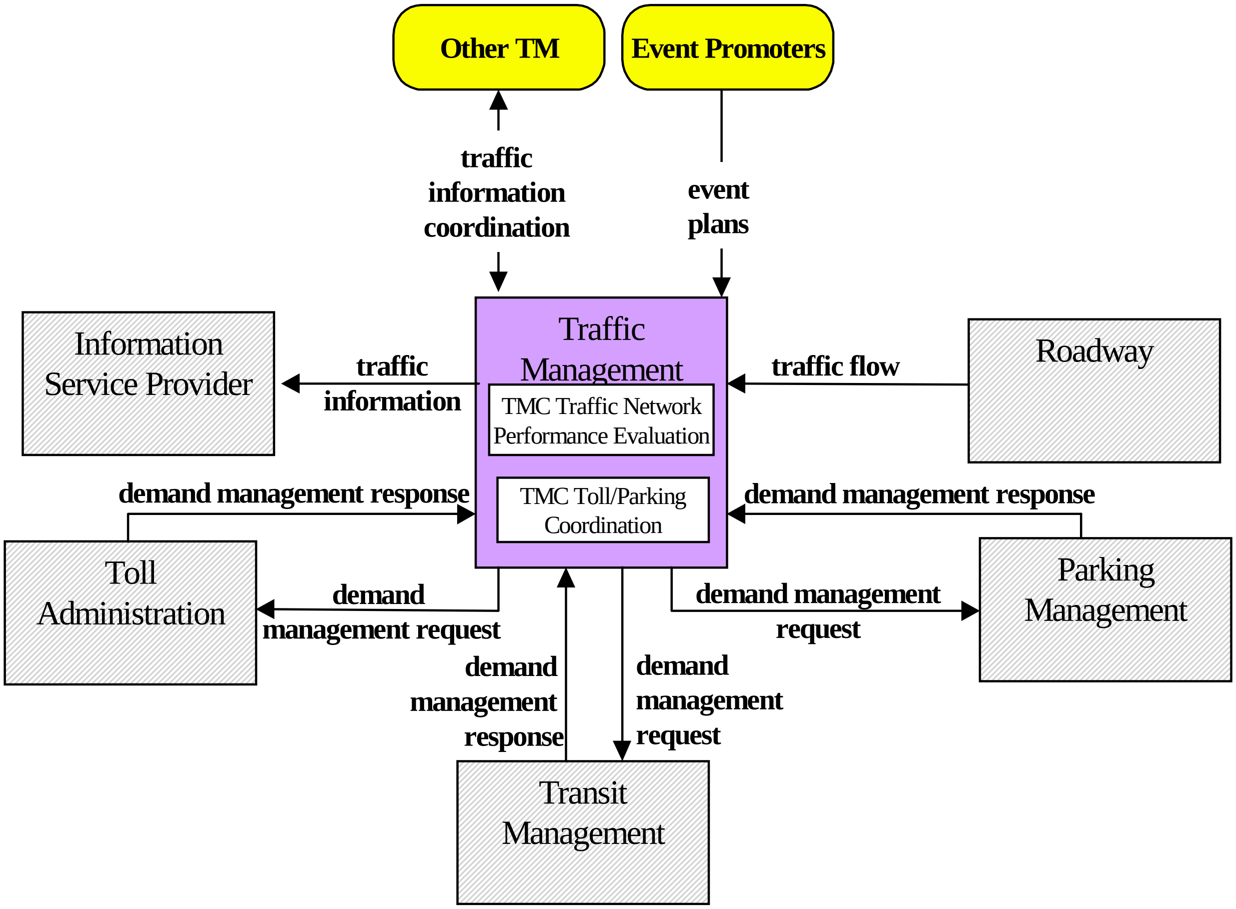
Incident Management System (ATMS8)

This market package manages both predicted and unexpected incidents so that the impact to the transportation network and traveler safety is minimized. Requisite incident detection capabilities are included in the freeway control market package and through the regional coordination with other traffic management and emergency management centers, weather service entities, and event promoters supported by this market package. Information from these diverse sources are collected and correlated by this market package to detect and verify incidents and implement an appropriate response. This market package provides Traffic Management Subsystem equipment that supports traffic operations personnel in developing an appropriate response in coordination with emergency management and other incident response personnel to confirmed incidents. The response may include traffic control strategy modifications and presentation of information to affected travelers using the Traffic Information Dissemination market package. The same equipment assists the operator by monitoring incident status as the response unfolds. The coordination with emergency management might be through a CAD system or through other communication with emergency field personnel. The coordination can also extend to tow trucks and other field service personnel.



Traffic Prediction and Demand Management (ATMS9)

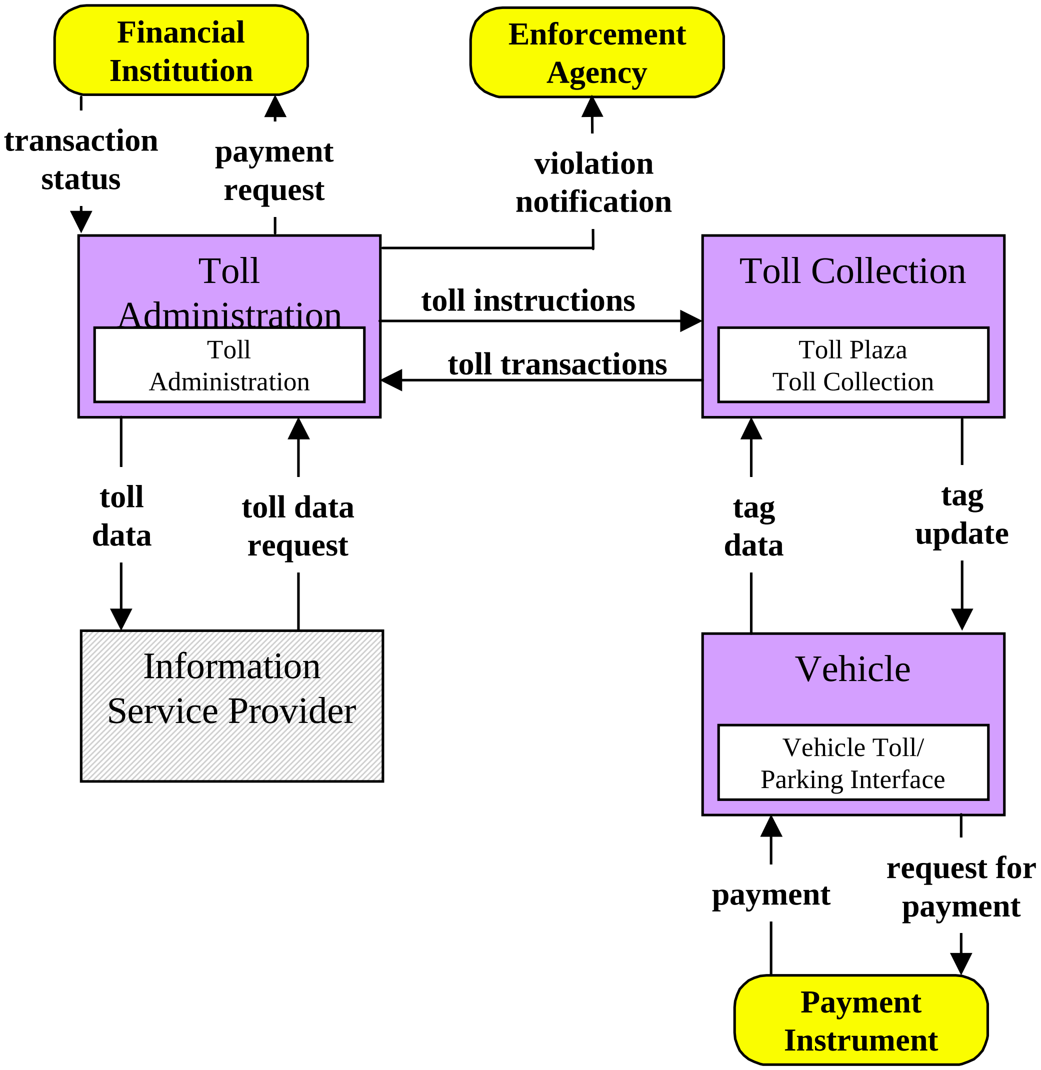
This market package includes advanced algorithms, processing, and mass storage capabilities that support historical evaluation, real-time assessment, and forecast of the roadway network performance. This includes the prediction of travel demand patterns to support better link travel time forecasts. The source data would come from the Traffic Management Subsystem itself as well as other traffic management centers and predicted traffic loads derived from route plans supplied by the Information Service Provider Subsystem. In addition to short term forecasts, this market package provides longer range forecasts that can be used in transportation planning. This market package provides data that supports the implementation of TDM programs, and policies managing both traffic and the environment. Information on vehicle pollution levels, parking availability, usage levels, and vehicle occupancy are collected by monitoring sensors to support these functions. Demand management requests can also be made to Toll Administration, Transit Management, and Parking Management Subsystems.



Electronic Toll Collection (ATMS10)

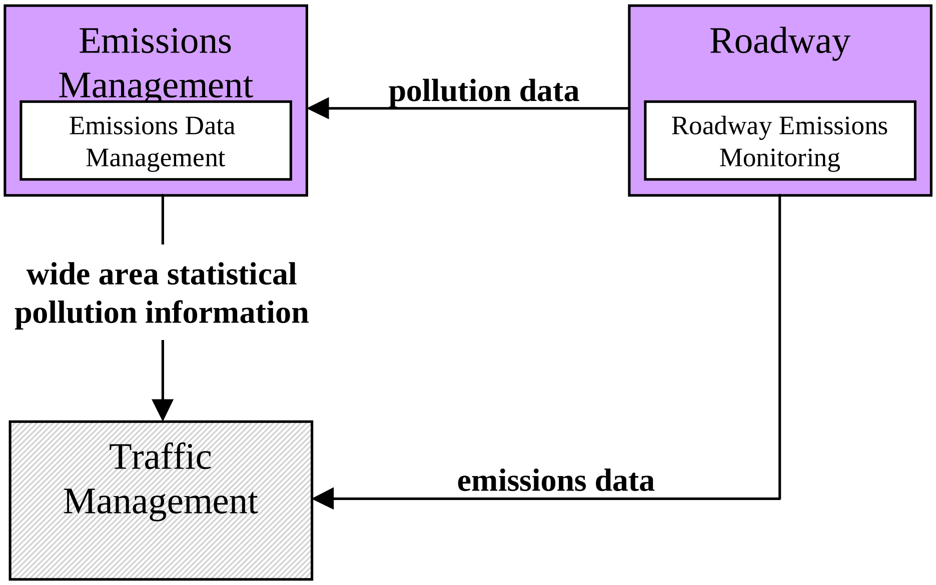
This market package provides toll operators with the ability to collect tolls electronically and detect and process violators. Variations in the fees that are collected enables implementation of demand management strategies. Dedicated short range communication between the roadway equipment and the vehicle is required as well as wireline interfaces between the toll collection equipment and transportation authorities and the financial infrastructure that supports fee collection. Vehicle tags of toll violators are read and electronically posted to vehicle owners. Standards, inter-agency coordination, and financial clearinghouse capabilities enable regional, and ultimately national interoperability for these services.

The population of toll tags and roadside readers that these systems utilize can also be used to collect road use statistics for highway authorities. This data can be collected as a natural by-product of the toll collection process or collected by separate readers that are dedicated to probe data collection.



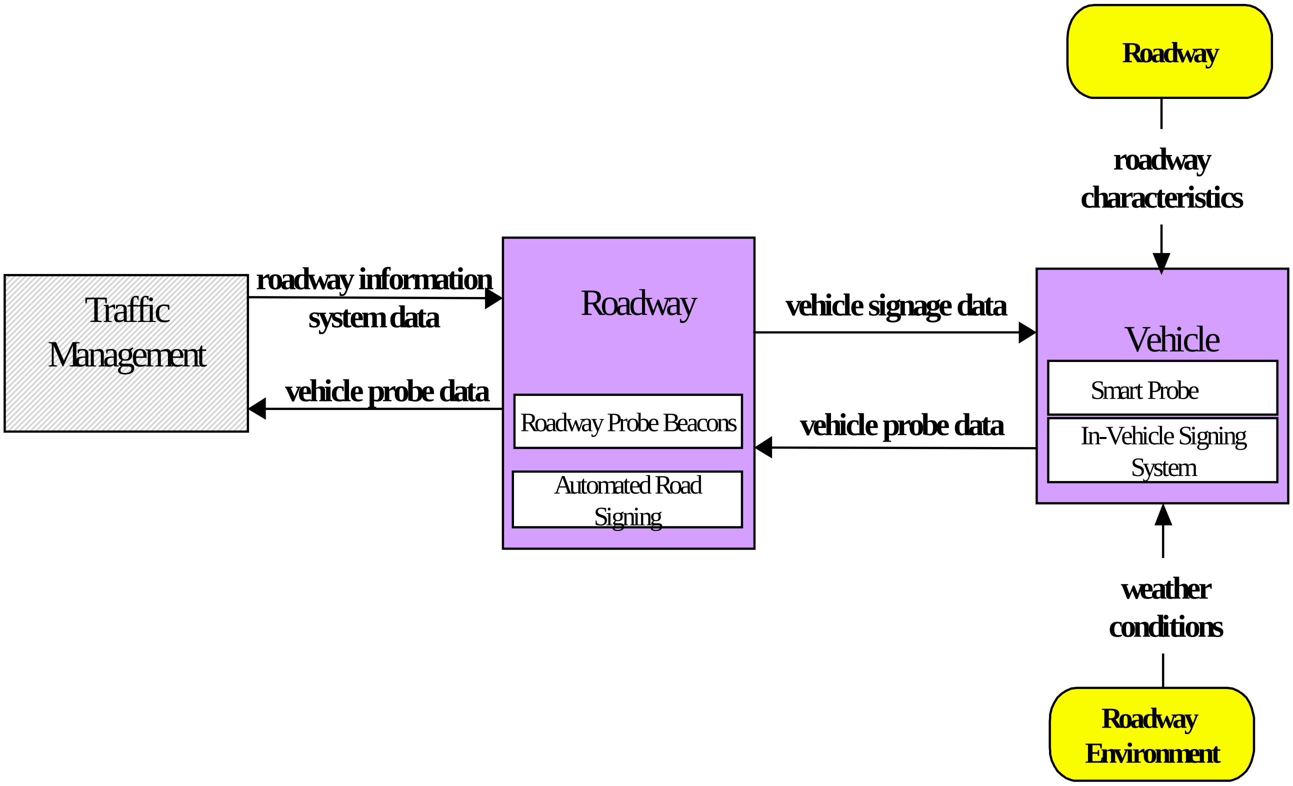
Emissions Monitoring and Management (ATMS11)

This market package monitors individual vehicle emissions and provides general air quality monitoring using distributed sensors to collect the data. The collected information is transmitted to the emissions management subsystem for processing. Both individual detection and identification of vehicles that exceed emissions standards and general area-wide monitoring of air quality are supported by this market package. For area wide monitoring, this market package measures air quality, identifies sectors that are non-compliant with air quality standards, and collects, stores and reports supporting statistical data. For point emissions monitoring, this market package measures tail pipe emissions and identifies vehicles that exceed emissions standards. The gathered information can be used to implement environmentally sensitive TDM programs, policies, and regulations.



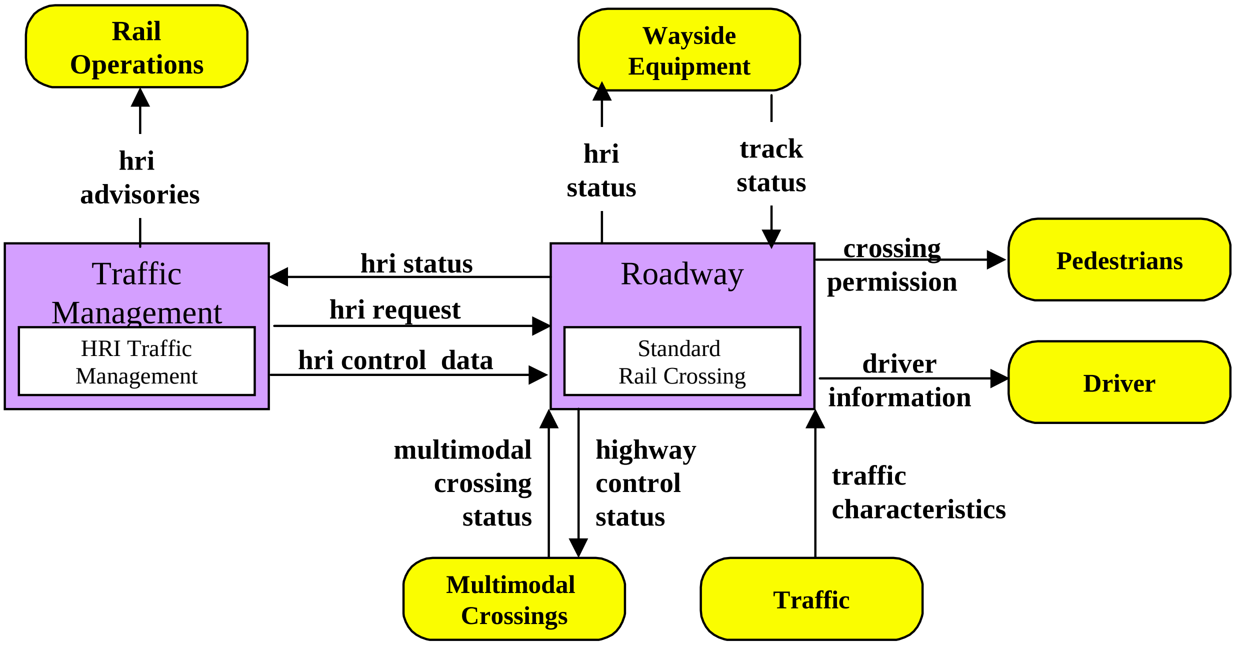
Virtual TMC and Smart Probe Data (ATMS12)

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



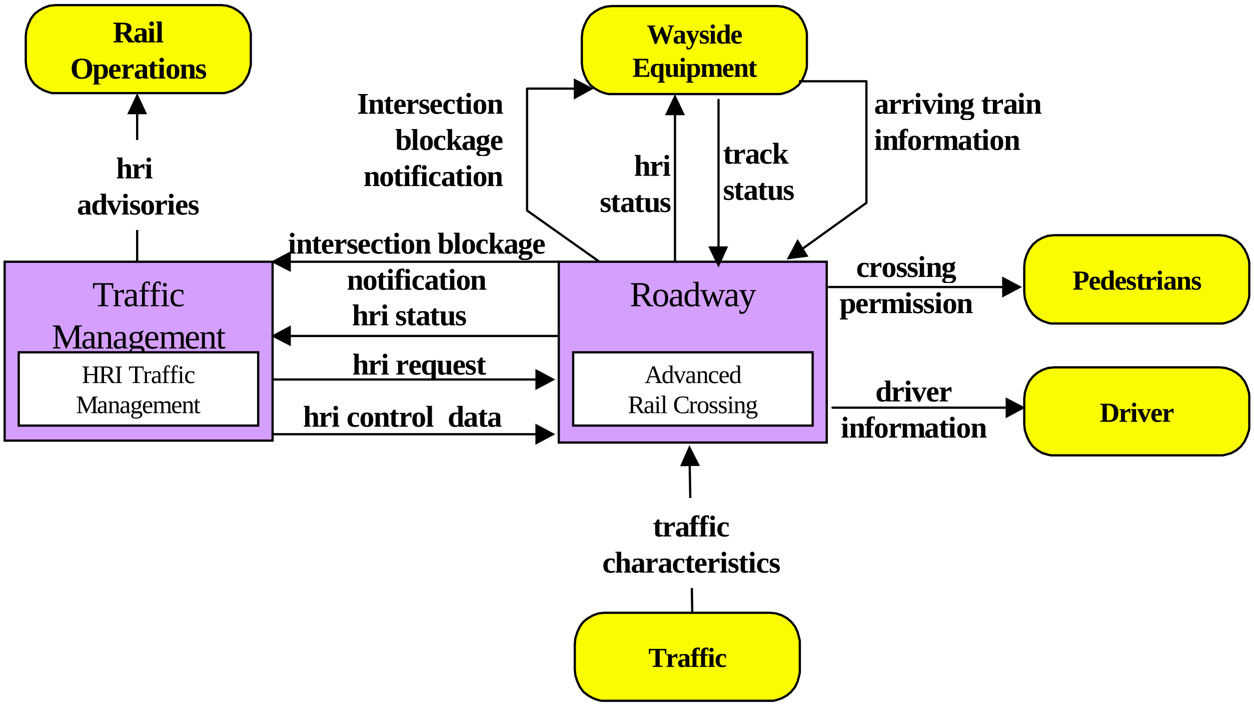
Standard Railroad Grade Crossing (ATMS13)

This market package manages highway traffic at highway-rail intersections (HRIs) where operational requirements do not dictate more advanced features (e.g., where rail operational speeds are less than 80 miles per hour). Both passive (e.g., the crossbuck sign) and active warning systems (e.g., flashing lights and gates) are supported. (Note that passive systems exercise only the single interface between the roadway subsystem and the driver in the architecture definition.) These traditional HRI warning systems may also be augmented with other standard traffic management devices. The warning systems are activated on notification by interfaced wayside equipment of an approaching train. The equipment at the HRI may also be interconnected with adjacent signalized intersections so that local control can be adapted to highway-rail intersection activities. Health monitoring of the HRI equipment and interfaces is performed; detected abnormalities are reported to both highway and railroad officials through wayside interfaces and interfaces to the traffic management subsystem.



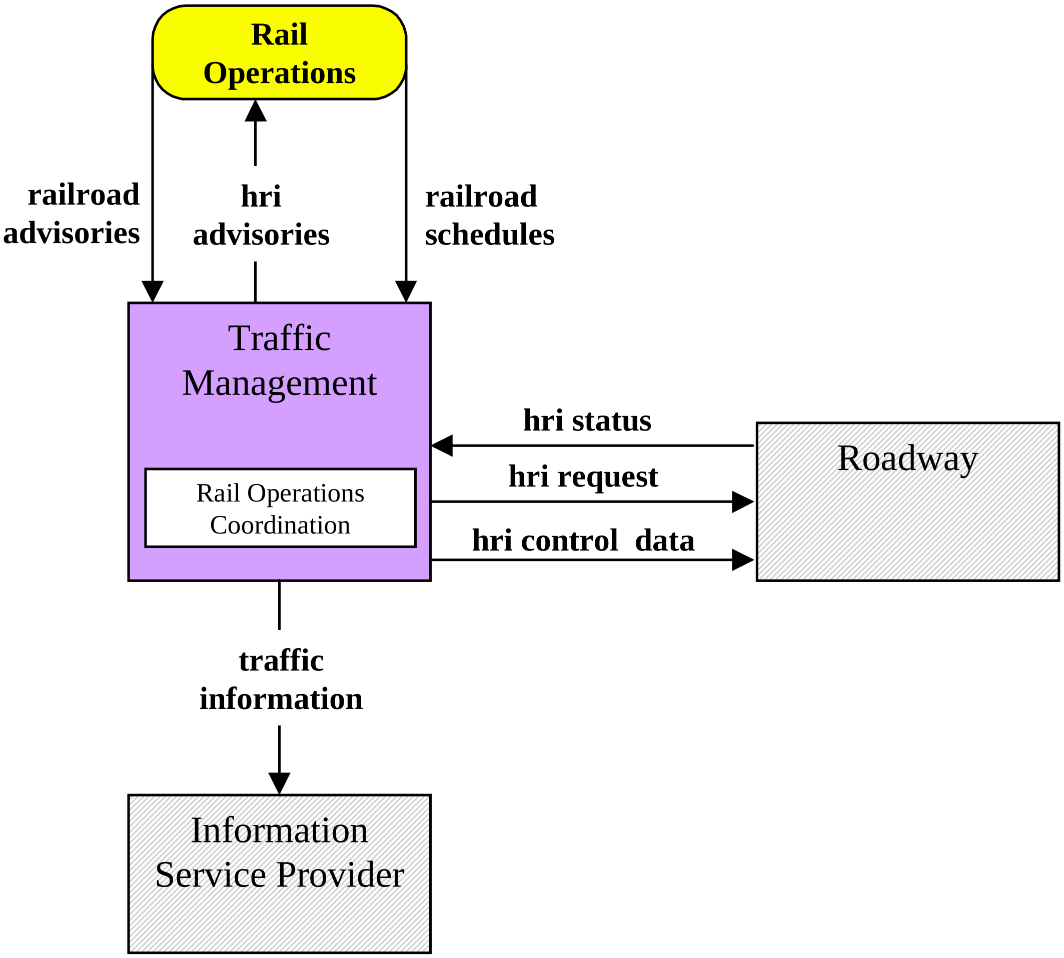
Advanced Railroad Grade Crossing (ATMS14)

This market package manages highway traffic at highway-rail intersections (HRIs) where operational requirements demand advanced features (e.g., where rail operational speeds are greater than 80 miles per hour). This market package includes all capabilities from the Standard Railroad Grade Crossing Market Package and augments these with additional safety features to mitigate the risks associated with higher rail speeds. The active warning systems supported by this market package include positive barrier systems, which preclude entrance into the intersection when the barriers are activated. Like the Standard Package, the HRI equipment is activated on notification by wayside interface equipment, which detects, or communicates with the approaching train. In this market package, additional information about the arriving train is also provided by the wayside interface equipment so that the train's direction of travel, its estimated time of arrival, and the estimated duration of closure may be derived. This enhanced information may be conveyed to the driver prior to, or in context with, warning system activation. This market package also includes additional detection capabilities, which enable it to detect an entrapped or otherwise immobilized vehicle within the HRI and provide an immediate notification to highway and railroad officials..



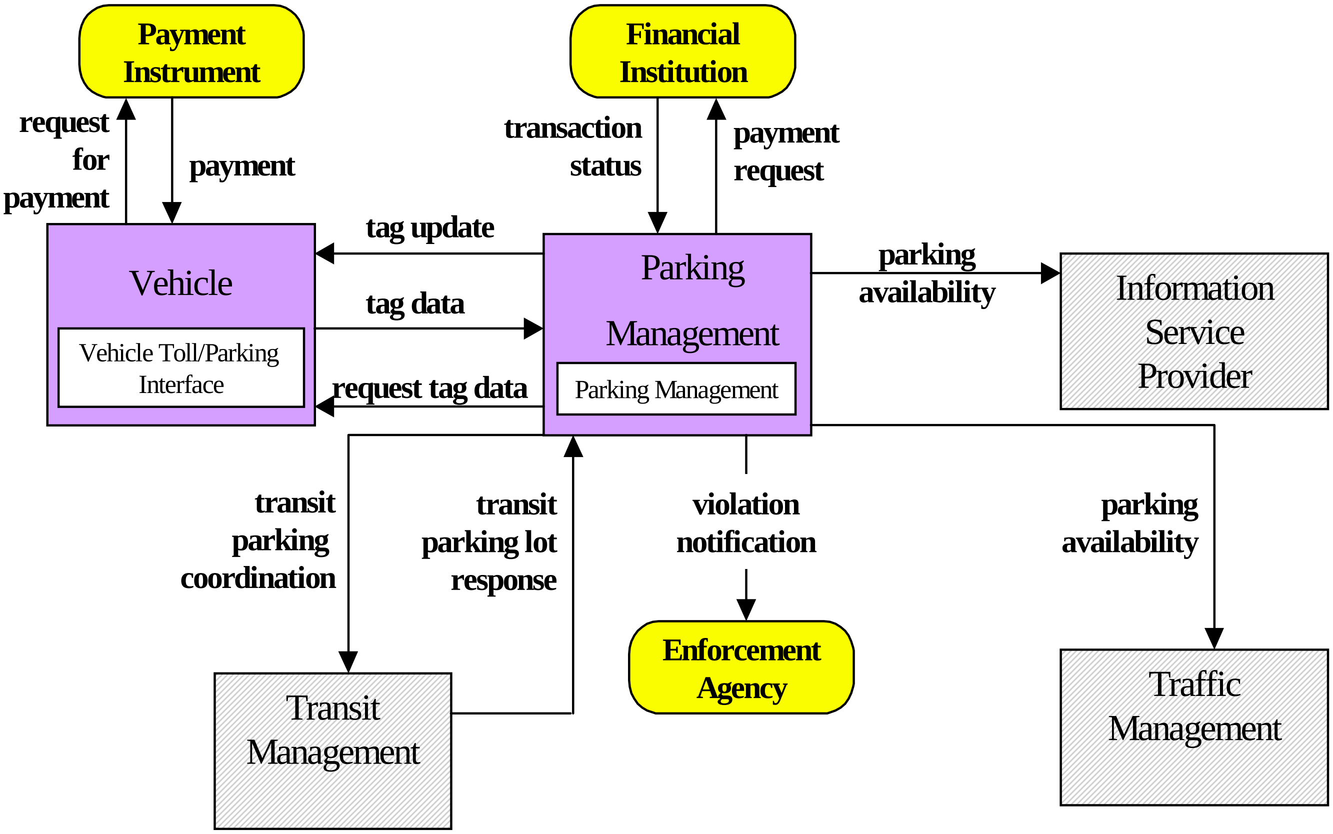
Railroad Operations Coordination (ATMS15)

This market package provides an additional level of strategic coordination between rail operations and traffic management centers. Rail operations provides train schedules, maintenance schedules, and any other forecast events which will result in highway-rail intersection (HRI) closures. This information is used to develop forecast HRI closure times and durations, which may be used in advanced traffic control strategies, or to enhance the quality of traveler information.



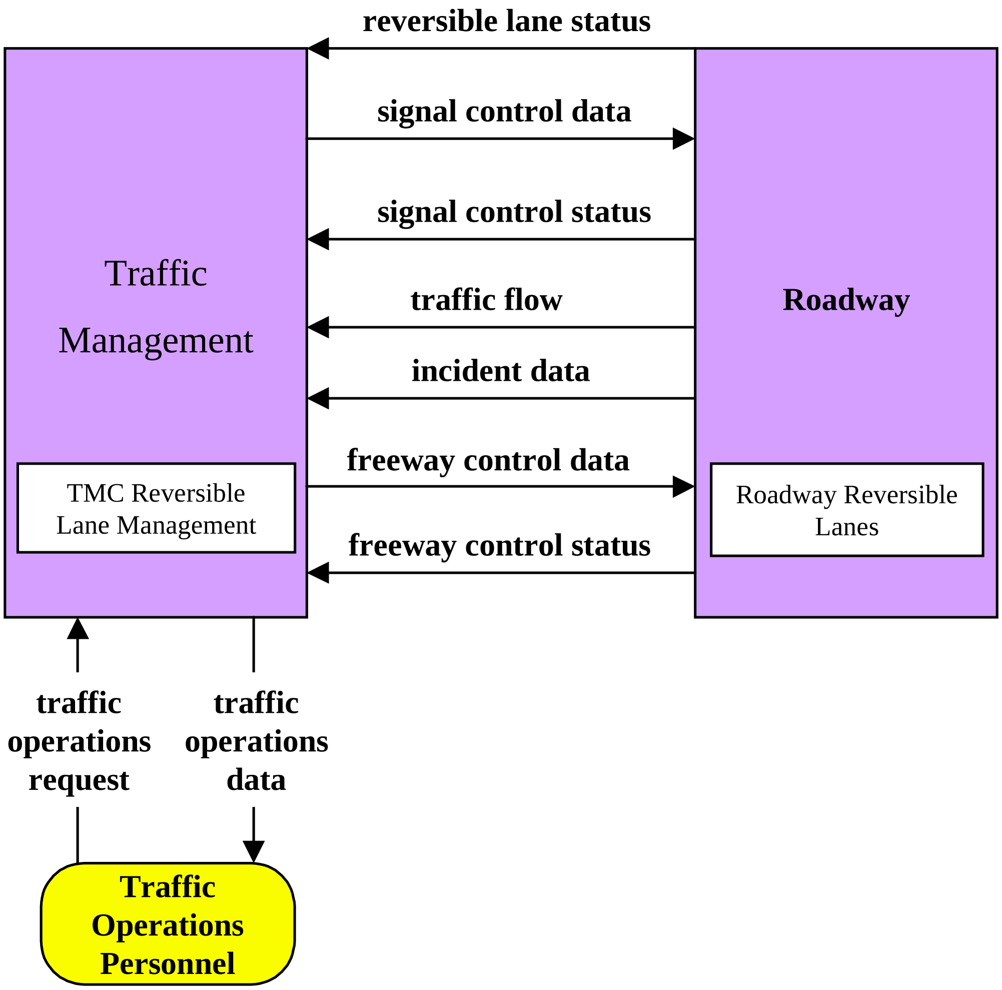
Parking Facility Management (ATMS16)

This market package provides enhanced monitoring and management of a parking facility. The included equipment assists in the management of parking operations, coordinates with transportation authorities, and supports electronic collection of parking fees. This is performed by sensing and collecting current parking facility status, sharing the data with information service providers and traffic operations, and automatic fee collection using short range communications with the same in-vehicle equipment utilized for electronic toll collection.



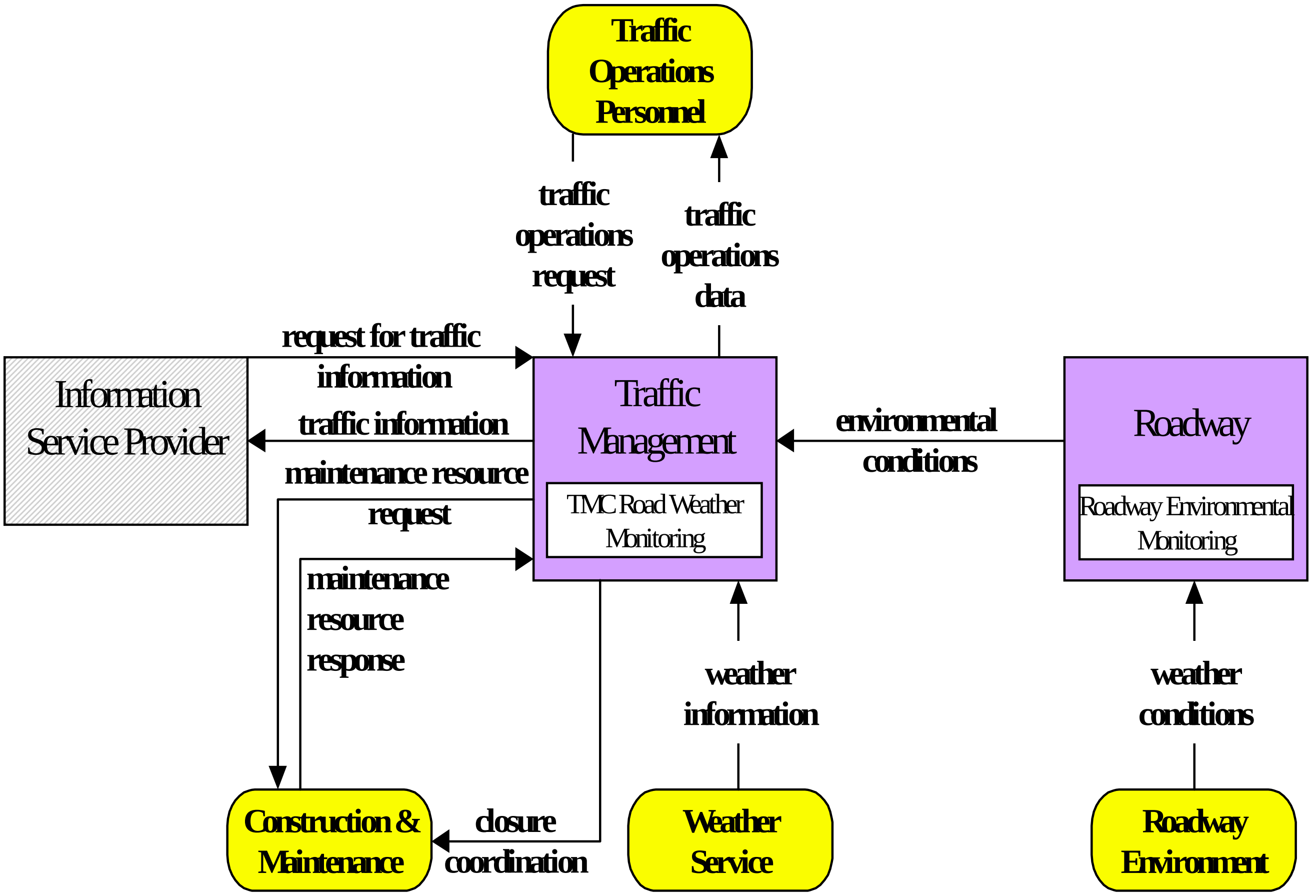
Reversible Lane Management (ATMS17)

This market package provides for the management of reversible lane facilities. In addition to standard surveillance capabilities, this market package includes sensory functions that detect wrong-way vehicles and other special surveillance capabilities that mitigate safety hazards associated with reversible lanes. The package includes the field equipment, physical lane access controls, and associated control electronics that manage and control these special lanes. This market package also includes the equipment used to electronically reconfigure intersections and manage right-of-way to address dynamic demand changes and special events.



Road Weather Information System (ATMS18)

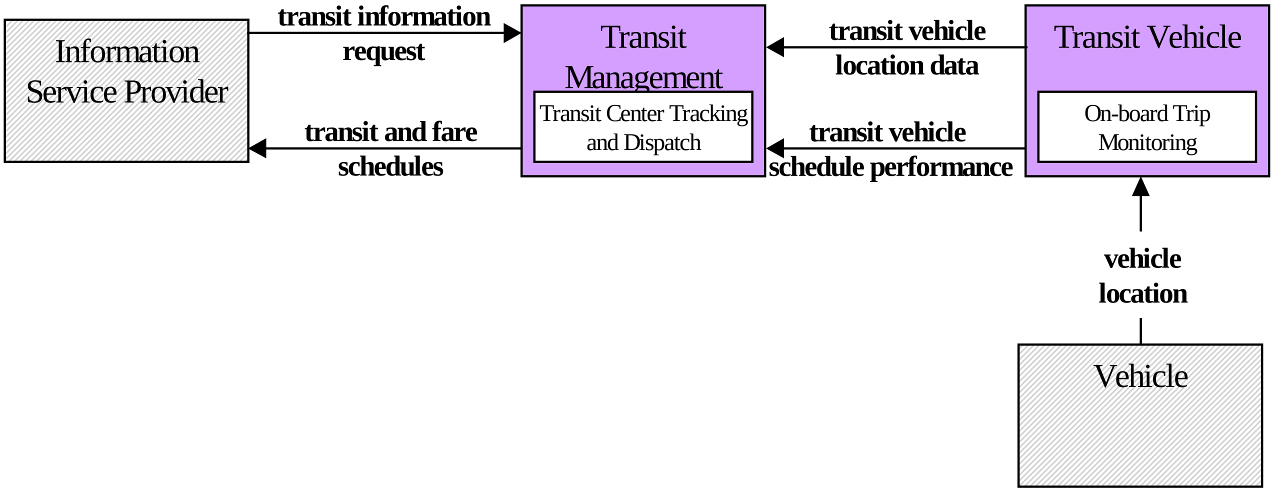
This market package monitors current and forecast road and weather conditions using a combination of weather service information and data collected from environmental sensors deployed on and about the roadway. The collected road weather information is monitored and analyzed to detect and forecast environmental hazards such as icy road conditions, dense fog, and approaching severe weather fronts. This information can be used to more effectively deploy road maintenance resources, issue general traveler advisories, and support location specific warnings to drivers using the Traffic Information Dissemination Market Package.



A.2 Public Transportation Market Packages

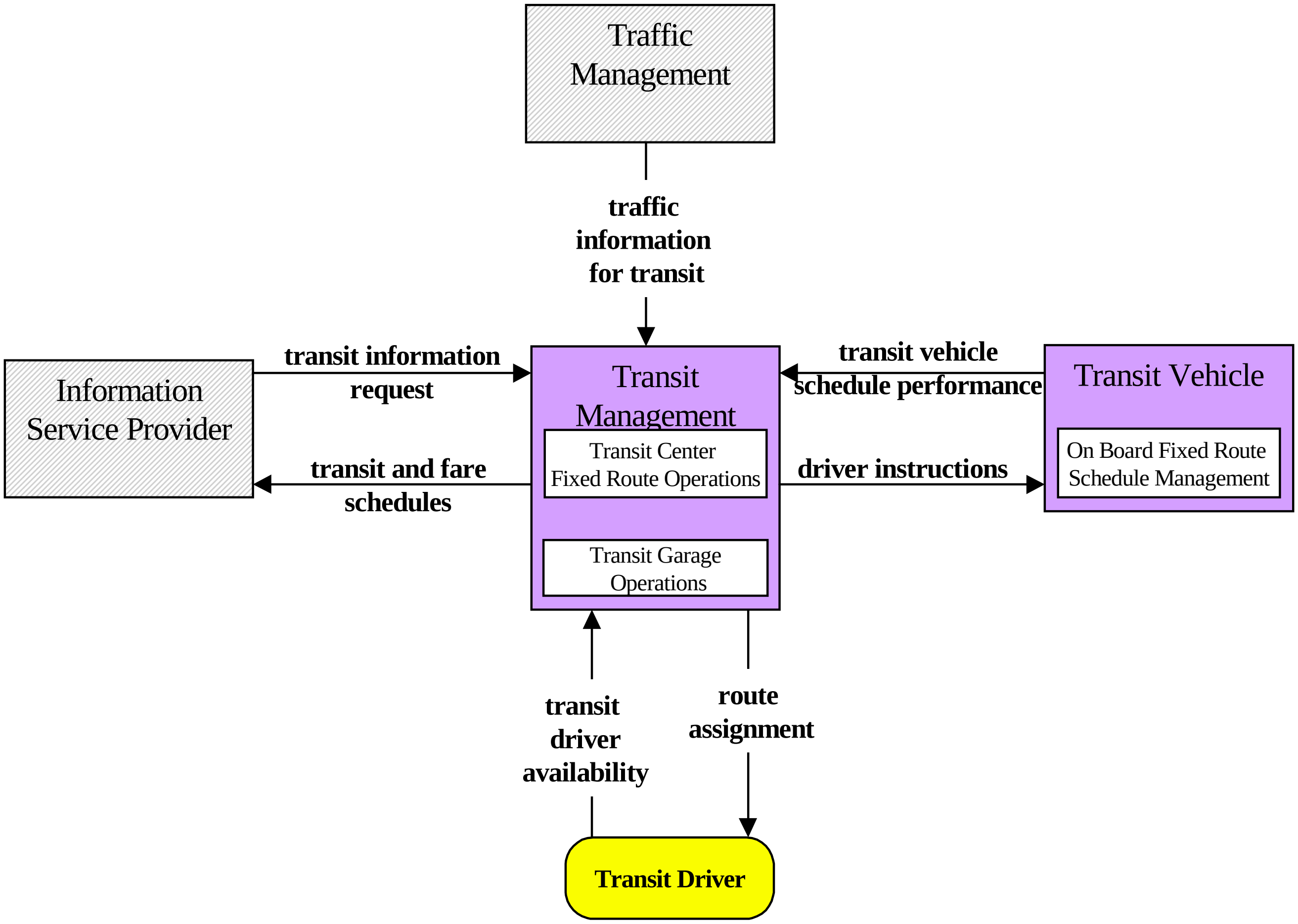
Transit Vehicle Tracking (APTS1)

This market package provides for an Automated Vehicle Location System to track the transit vehicle's real time schedule adherence and updates the transit system's schedule in real-time. Vehicle position may be determined either by the vehicle (e.g., through GPS) and relayed to the infrastructure or may be determined directly by the communications infrastructure. A two-way wireless communication link with the Transit Management Subsystem is used for relaying vehicle position and control measures. Fixed route transit systems may also employ beacons along the route to enable position determination and facilitate communications with each vehicle at fixed intervals. The Transit Management Subsystem processes this information, updates the transit schedule and makes real-time schedule information available to the Information Service Provider Subsystem via a wireline link.



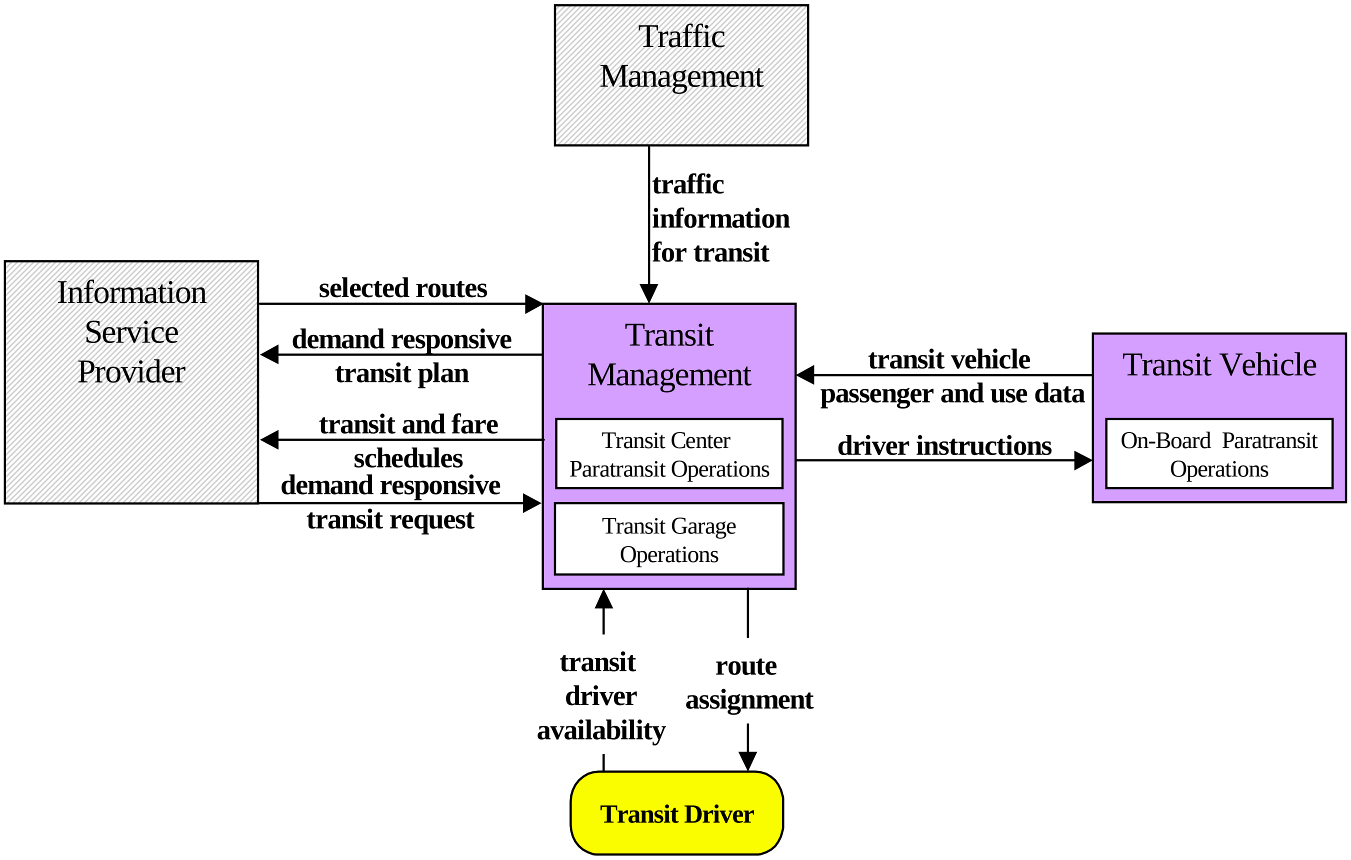
Transit Fixed-Route Operations (APTS2)

This market package performs automatic driver assignment and monitoring, as well as vehicle routing and scheduling for fixed-route services. This service uses the existing AVL database as a source for current schedule performance data, and is implemented through data processing and information display at the transit management subsystem. This data is exchanged using the existing wireline link to the information service provider where it is integrated with that from other transportation modes (e.g. rail, ferry, air) to provide the public with integrated and personalized dynamic schedules



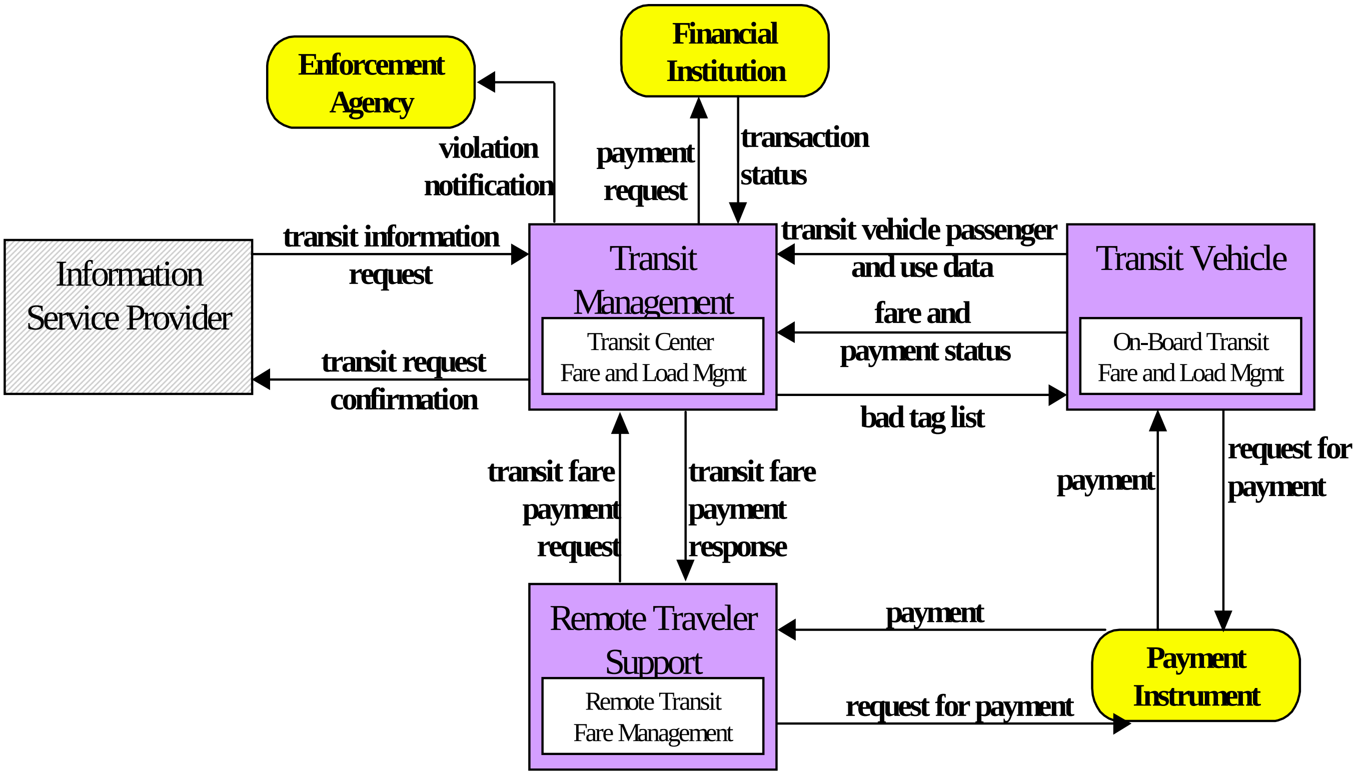
Demand Response Transit Operations (APTS3)

This market package performs automatic driver assignment and monitoring as well as vehicle routing and scheduling for demand response transit services. This package uses the existing AVL database to monitor current status of the transit fleet and supports allocation of these fleet resources to service incoming requests for transit service while also considering traffic conditions. The Transit Management Subsystem provides the necessary data processing and information display to assist the transit operator in making optimal use of the transit fleet. The Information Service Provider Subsystem may be either be operated by transit management center or be independently owned and operated by a separate service provider. In the first scenario, the traveler makes a direct request to a specific paratransit service. In the second scenario, a third party service provider determines the paratransit service is a viable means of satisfying a traveler request and uses wireline communications to make a reservation for the traveler.



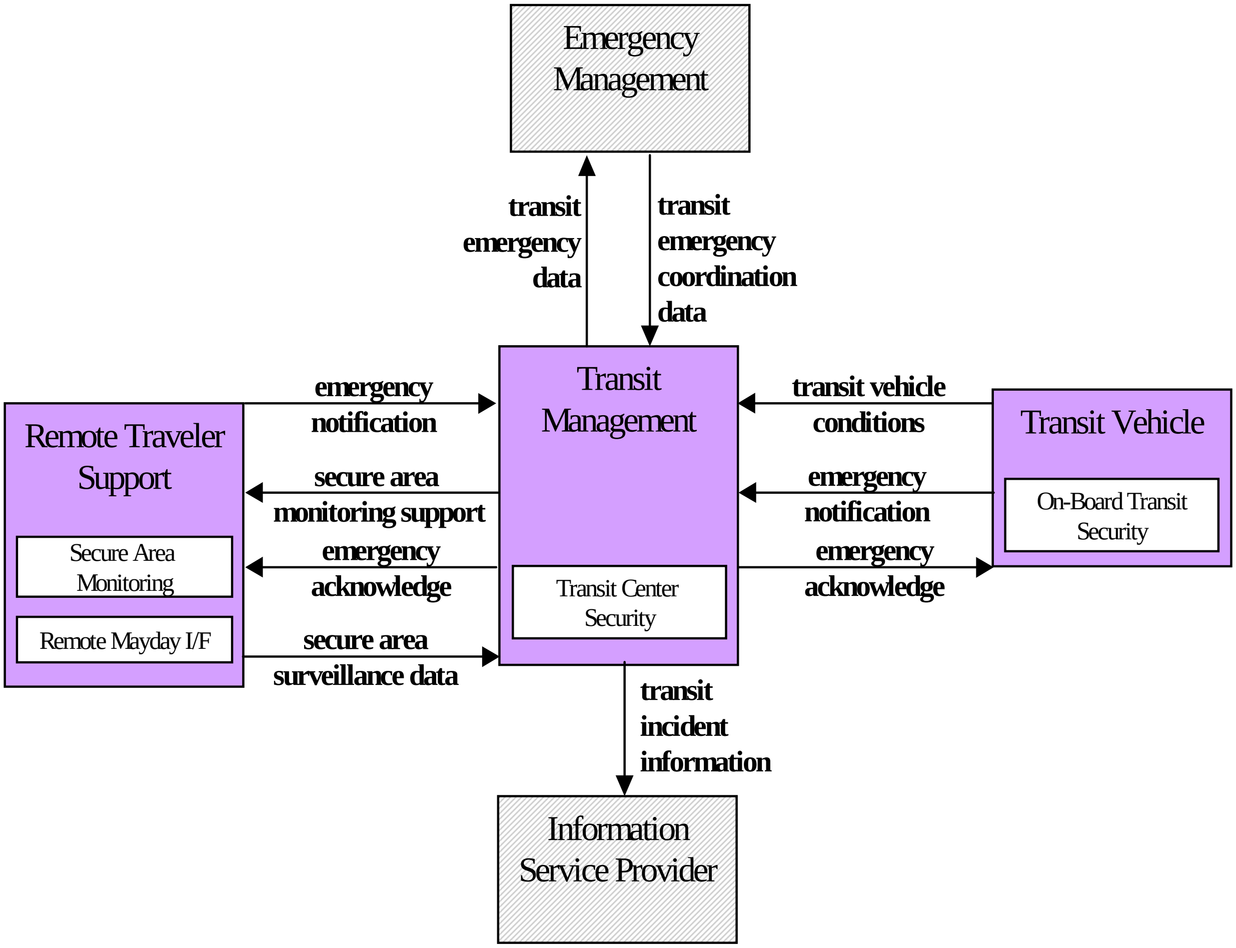
Transit Passenger and Fare Management (APTS4)

This market package allows for the management of passenger loading and fare payments on-board vehicles using electronic means. The payment instrument may be either a stored value or credit card. This package is implemented with sensors mounted on the vehicle to permit the driver and central operations to determine vehicle loads, and readers located either in the infrastructure or on-board the transit vehicle to allow fare payment. Data is processed, stored, and displayed on the transit vehicle and communicated as needed to the Transit Management Subsystem using existing wireless infrastructure.



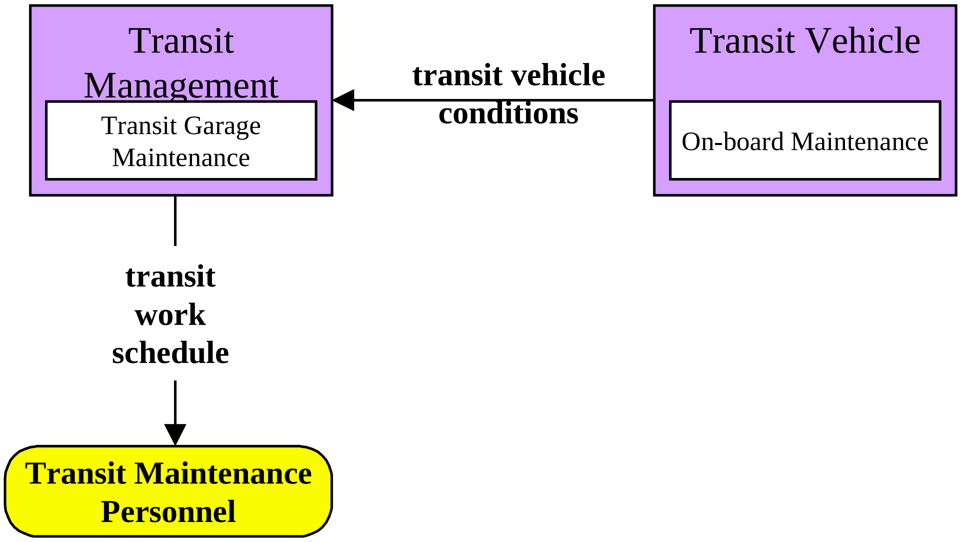
Transit Security (APTS5)

This market package provides for the physical security of transit passengers. An on-board security system is deployed to perform surveillance and warn of potentially hazardous situations. Public areas (e.g. stops, park and ride lots, stations) are also monitored. Information is communicated to the Transit Management Subsystem using the existing or emerging wireless (vehicle to center) or wireline (area to center) infrastructure. Security related information is also transmitted to the Emergency Management Subsystem when an emergency is identified that requires an external response. Incident information is communicated to the Information Service Provider.



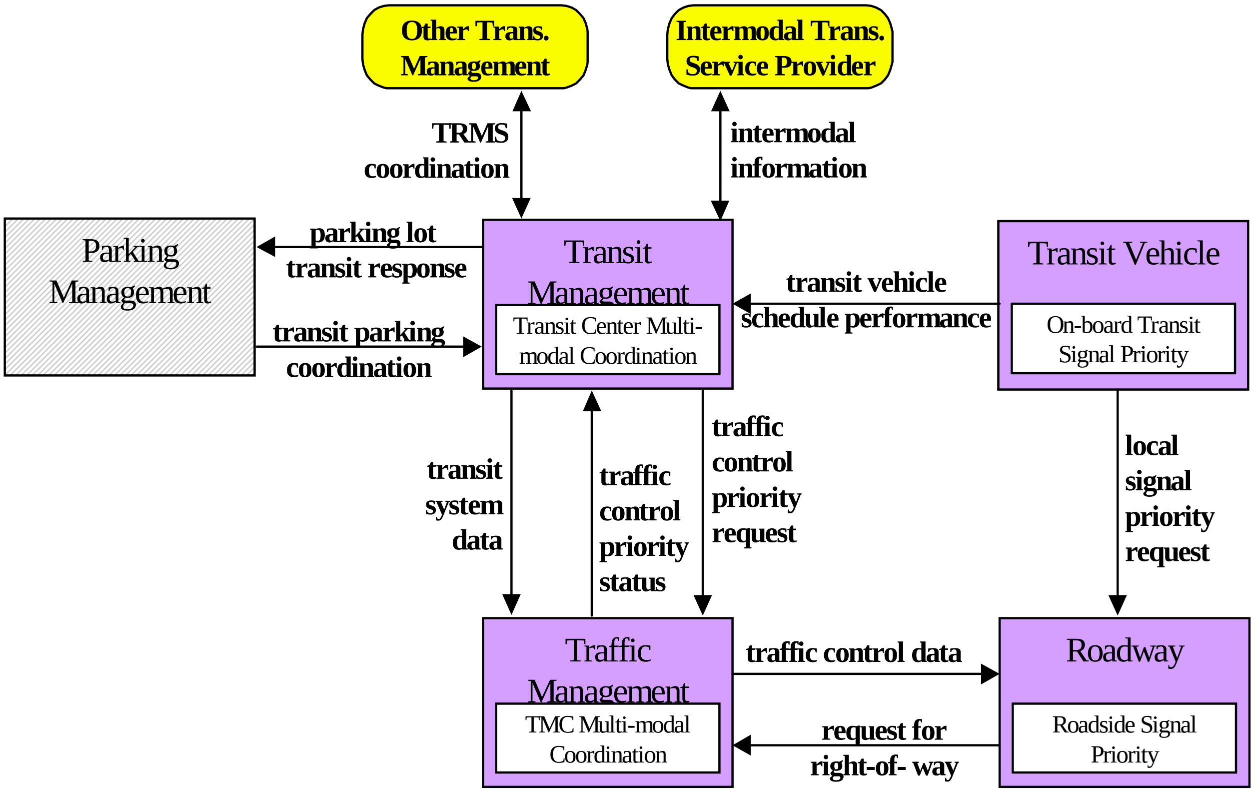
Transit Maintenance (APTS6)

This market package supports automatic maintenance scheduling and monitoring. On-board condition sensors monitor critical system status and transmit critical status information to the Transit Management Subsystem. Hardware and software in the Transit Management Subsystem processes this data and schedules maintenance activity.



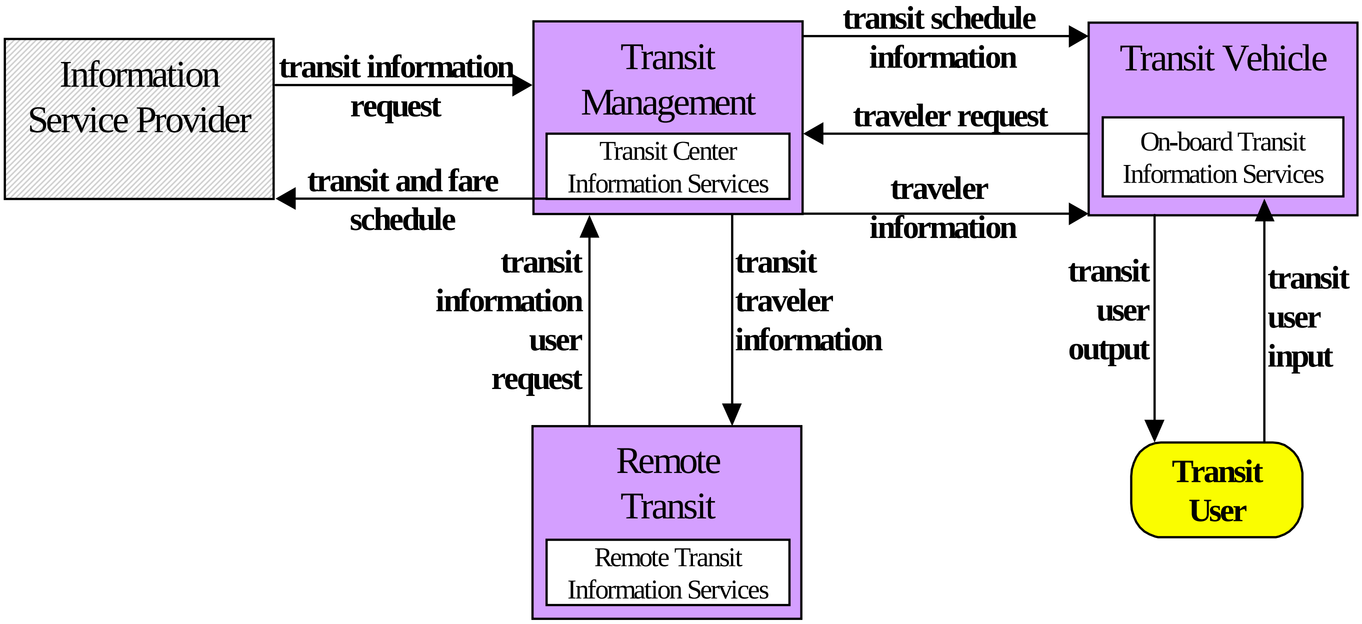
Multi-modal Coordination (APTS7)

This market package establishes two way communications between multiple transit and traffic agencies to improve service coordination. Intermodal coordination between transit agencies can increase traveler convenience at transfer points and also improve operating efficiency. Coordination between traffic and transit management is intended to improve on-time performance of the transit system to the extent that this can be accommodated without degrading overall performance of the traffic network. More limited local coordination between the transit vehicle and the individual intersection for signal priority is also supported by this package.



Transit Traveler Information (APTS8)

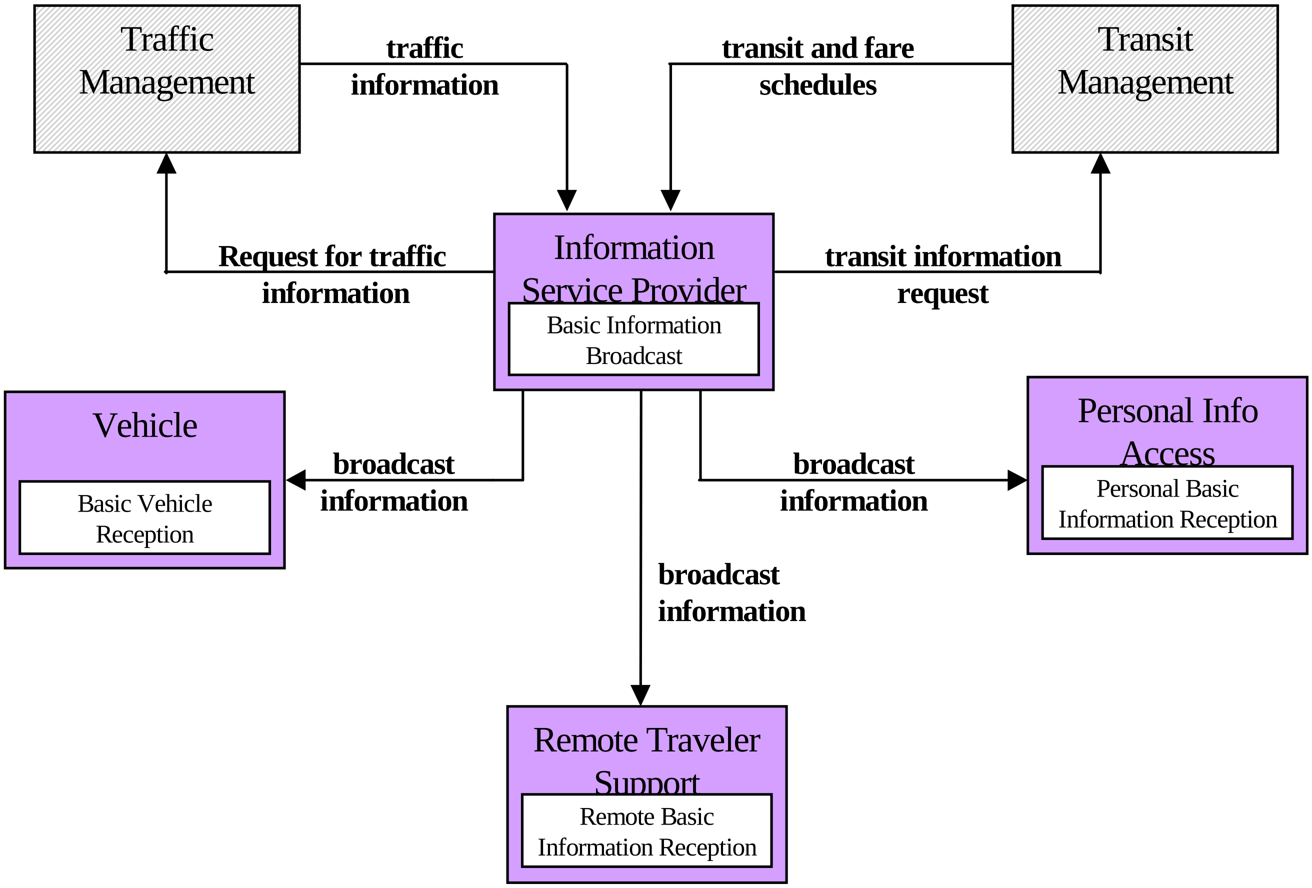
This market package provides transit users at transit stops and on-board transit vehicles with ready access to transit information. The information services include transit stop annunciation, imminent arrival signs, and real-time transit schedule displays that are of general interest to transit users. Systems that provide custom transit trip itineraries and other tailored transit information services are also represented by this market package.



A.3 Traveler Information Market Packages

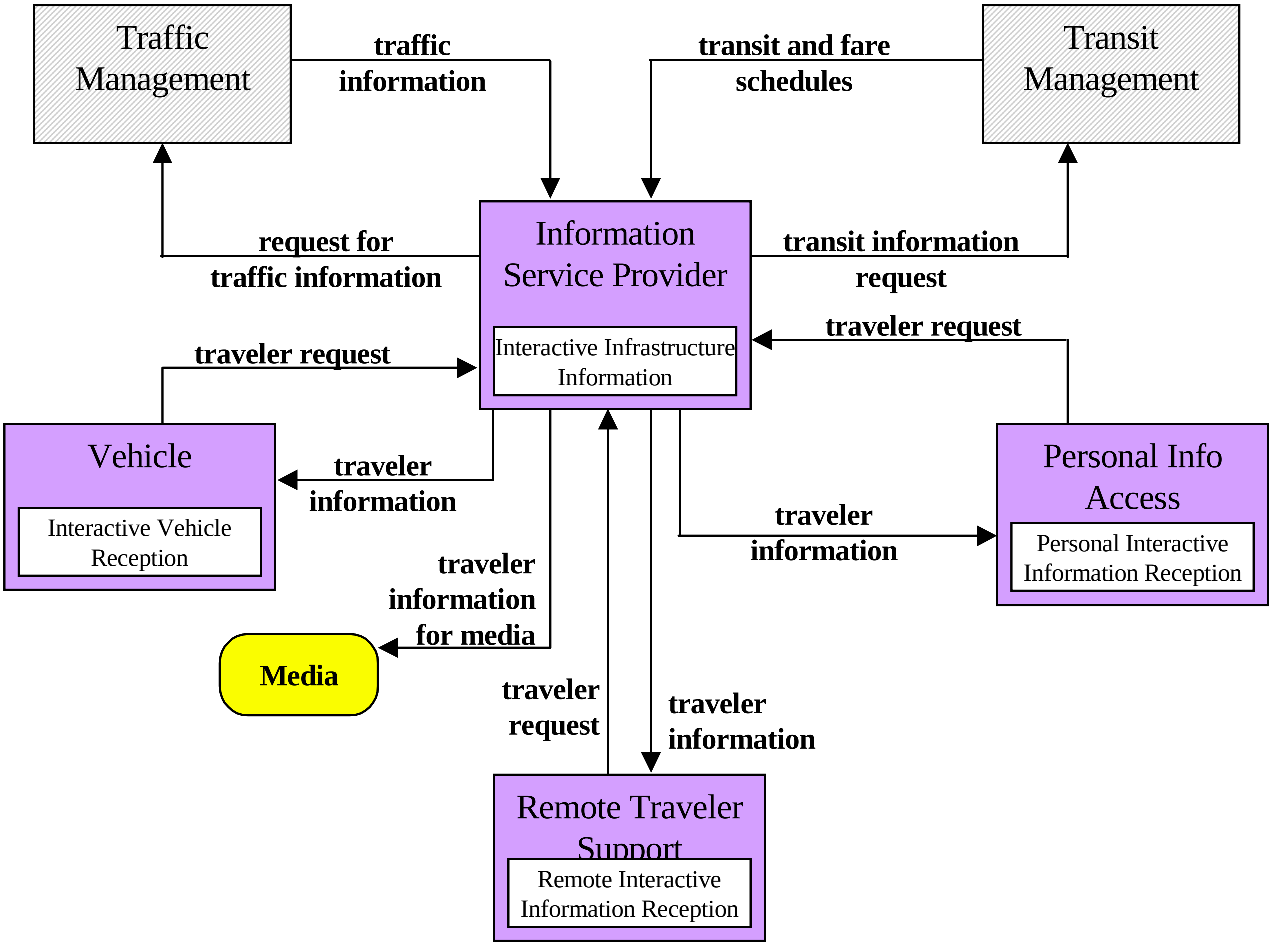
Broadcast Traveler Information (ATIS1)

This market package provides the user with a basic set of ATIS services; its objective is early acceptance. It involves the collection of traffic conditions, advisories, general public transportation and parking information and the near real time dissemination of this information over a wide area through existing infrastructures and low cost user equipment (e.g., FM subcarrier, cellular data broadcast). Different from the market package ATMS6--Traffic Information Dissemination--which provides the more basic HAR and VMS information capabilities, ATIS1 provides the more sophisticated digital broadcast service. Successful deployment of this market package relies on availability of real-time transportation data from roadway instrumentation, probe vehicles or other means.



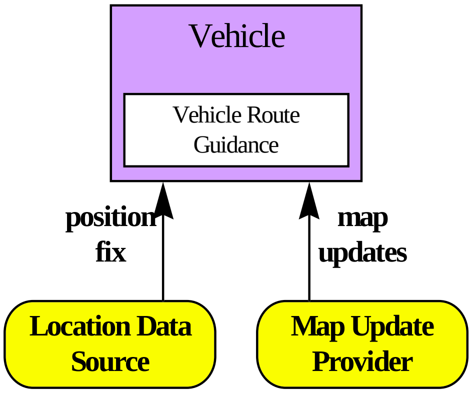
Interactive Traveler Information (ATIS2)

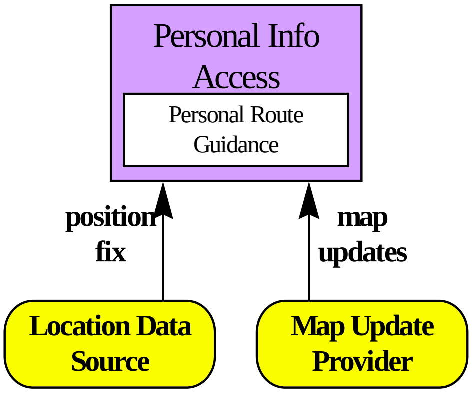
This market package provides tailored information in response to a traveler request. Both real-time interactive request/response systems and information systems that "push" a tailored stream of information to the traveler based on a submitted profile are supported. The traveler can obtain current information regarding traffic conditions, transit services, traveler services, ride share/ride match, parking management, and pricing information. A range of two-way wide-area wireless and wireline communications systems may be used to support the required digital communications between traveler and the information service provider. A variety of interactive devices may be used by the traveler to access information prior to a trip or en-route to include phone, kiosk, Personal Digital Assistant, personal computer, and a variety of in-vehicle devices. Successful deployment of this market package relies on availability of real-time transportation data from roadway instrumentation, probe vehicles or other means.



Autonomous Route Guidance (ATIS3)

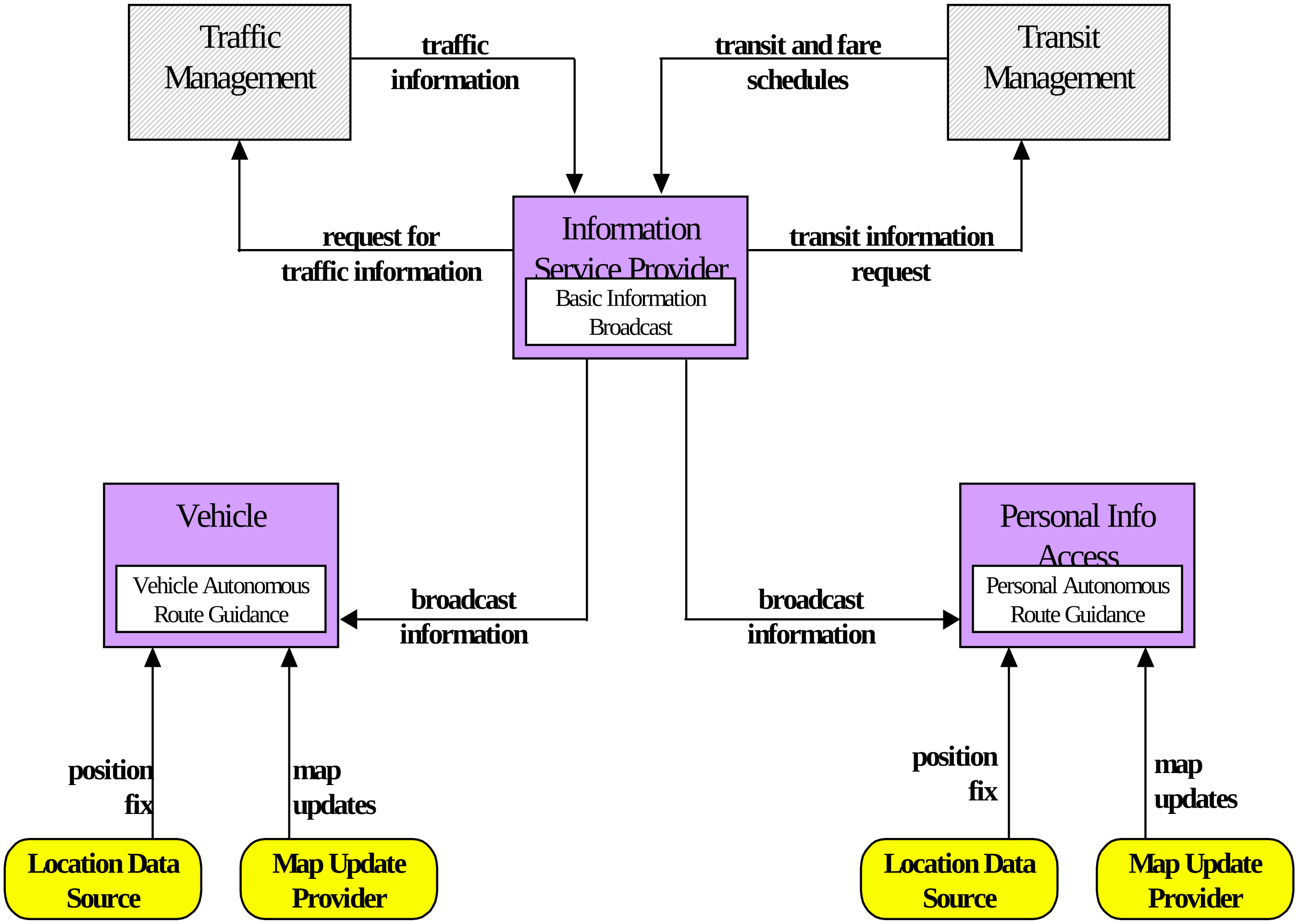
This market package relies on in-vehicle sensory, location determination, computational, map database, and interactive driver interface equipment to enable route planning and detailed route guidance based on static, stored information. No communication with the infrastructure is assumed or required. Identical capabilities are available to the traveler outside the vehicle by integrating a similar suite of equipment into portable devices.





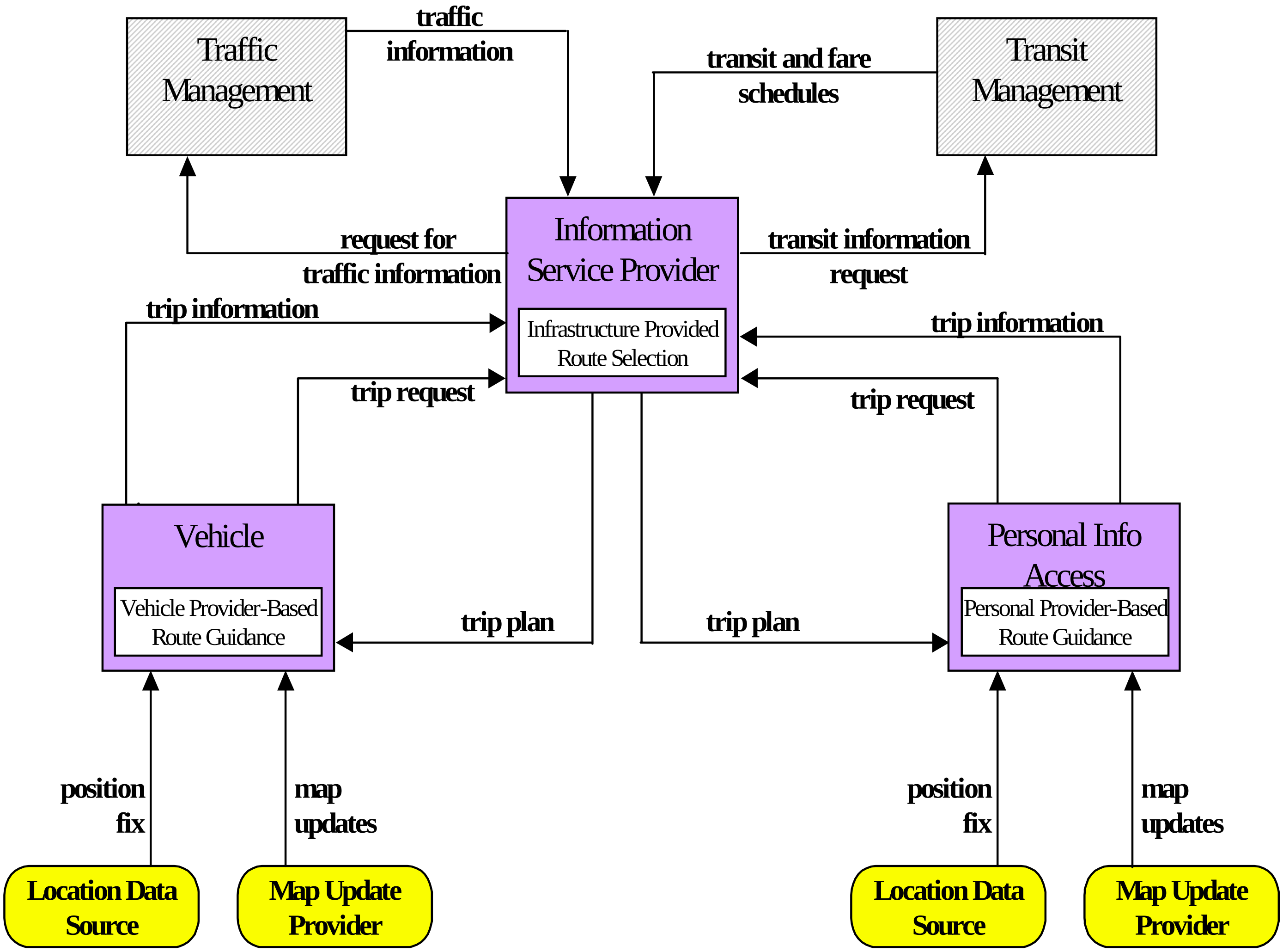
Dynamic Route Guidance (ATIS4)

This market package offers the user advanced route planning and guidance which is responsive to current conditions. The package combines the autonomous route guidance user equipment with a digital receiver capable of receiving real-time traffic, transit, and road condition information which is considered by the user equipment in provision of route guidance.



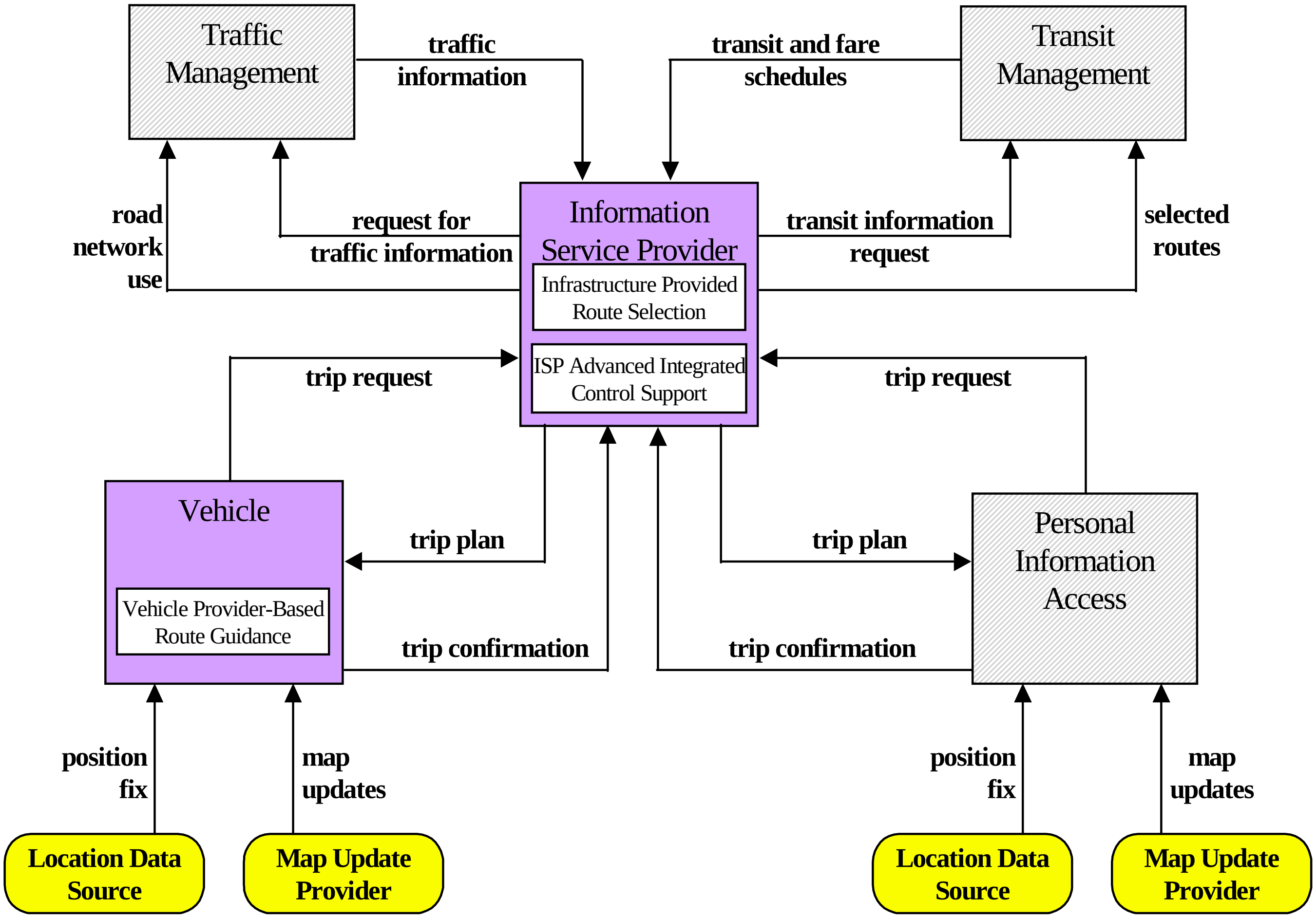
ISP-Based Route Guidance (ATIS5)

This market package offers the user advanced route planning and guidance which is responsive to current conditions. Different than the Dynamic Route Guidance Market Package, this market package moves the route planning function from the user device to the information service provider. This approach simplifies the user equipment requirements and can provide the infrastructure better information on which to predict future traffic and appropriate control strategies to support basic route planning with minimal user equipment. The package includes two way data communications and optionally also equips the vehicle with the databases, location determination capability, and display technology to support turn by turn route guidance.



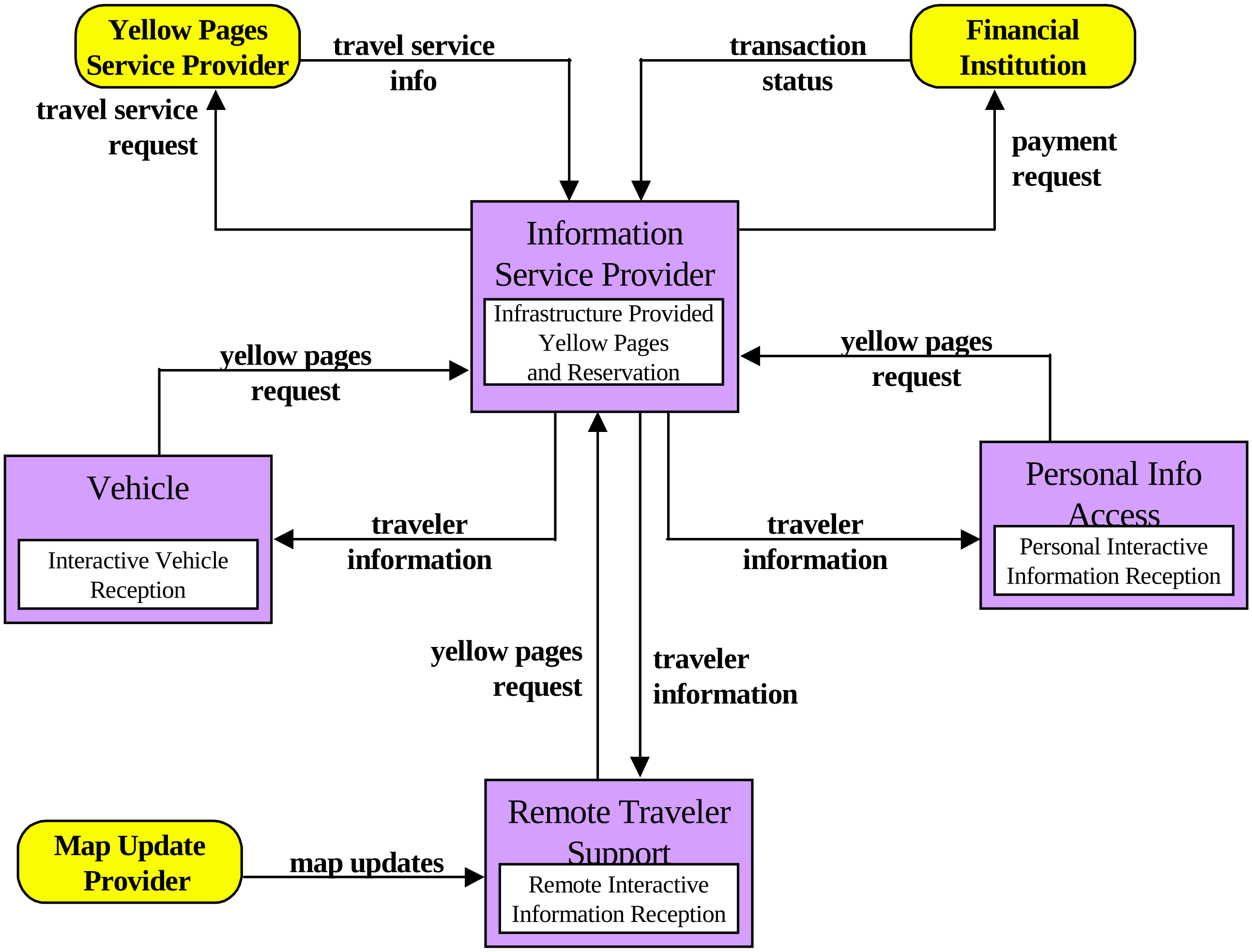
Integrated Transportation Management/Route Guidance (ATIS6)

This market package allows a traffic management center to continuously optimize the traffic control strategy based on near-real time information on intended routes for a proportion of the vehicles within their network while offering the user advanced route planning and guidance which is responsive to current conditions . It would utilize the individual and ISP route planning information to optimize signal timing while at the same time providing updated signal timing information to allow optimized route plans. The use of predictive link times for this market package are possible through utilizing the market package ATMS9--Traffic Prediction and Demand Management--at the traffic management center.



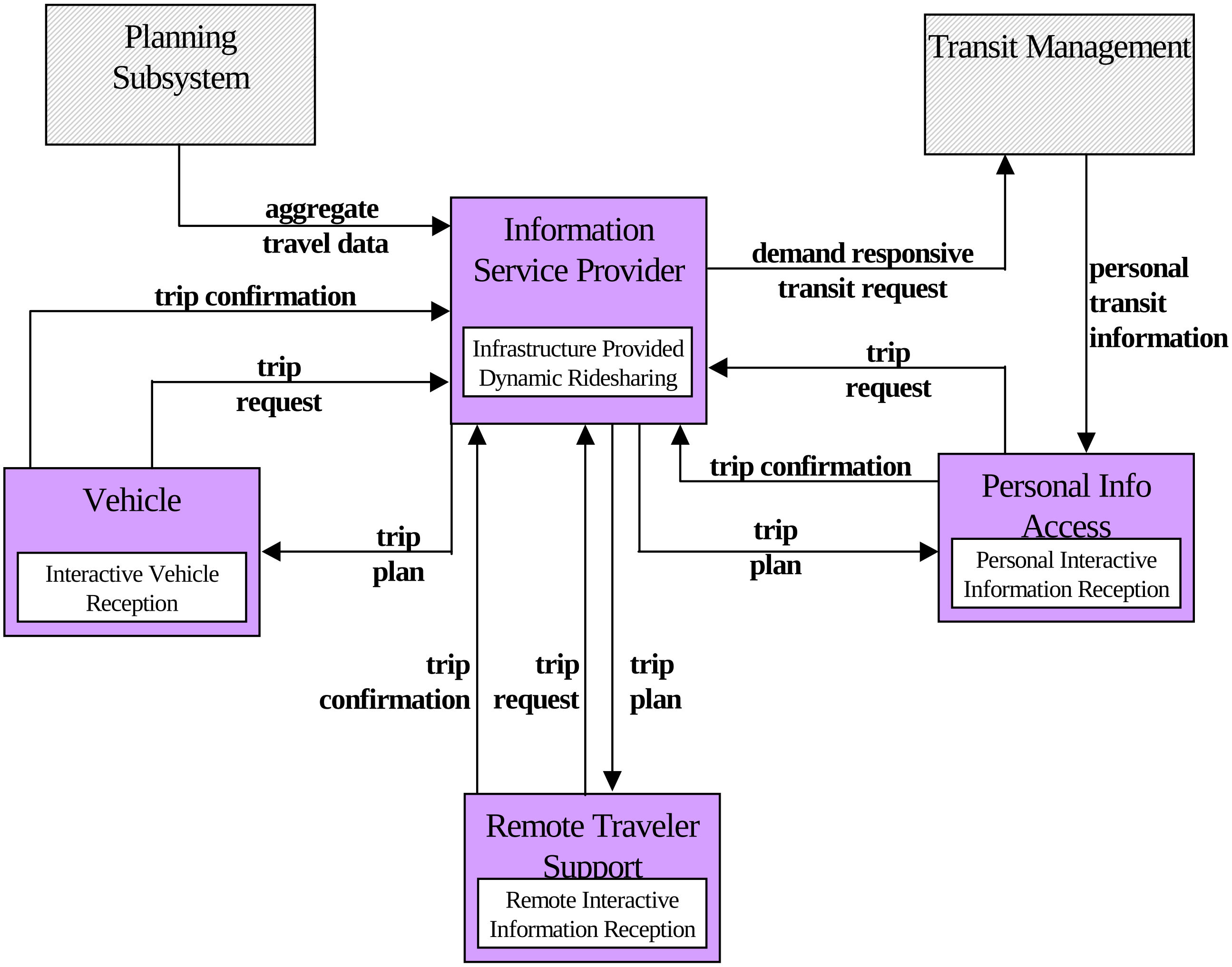
Yellow Pages and Reservation (ATIS7)

This market package enhances the Interactive Traveler Information package by adding infrastructure provided yellow pages and reservation capabilities to tailored requests for information regarding traffic conditions, transit services, traveler services, ride share/ride match, parking management, and pricing information. The same basic user equipment is included; service or advertising fees should allow recovery of the ISP investment. This market package provides multiple ways for accessing information such either while en-route in a vehicle using wide-area wireless communications or pre-trip via wireline connections.



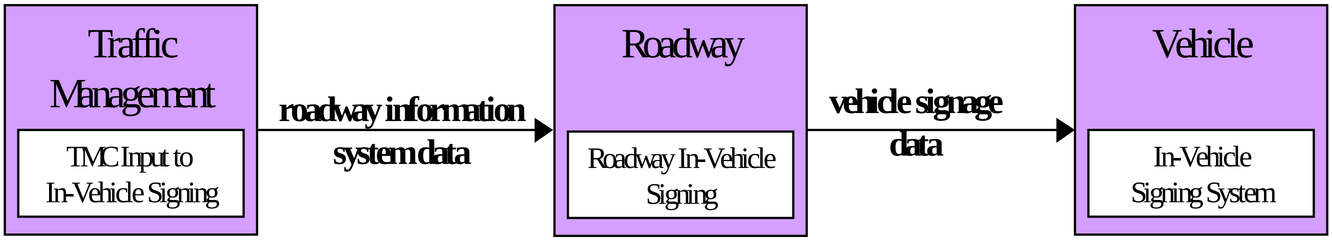
Dynamic Ridesharing (ATIS8)

This market package enhances the Interactive Traveler Information package by adding infrastructure provided dynamic ridesharing capability to tailored requests for information regarding traffic conditions, transit services, traveler services, ride share/ride match, parking management, and pricing information. The investment to the driver or traveler should not increase. If this service is provided by a private ISP, service fees may be required to allow for recovery of the ISP investment. In terms of equipment requirements, ATIS8 is similar to ATIS7.



In Vehicle Signing (ATIS9)

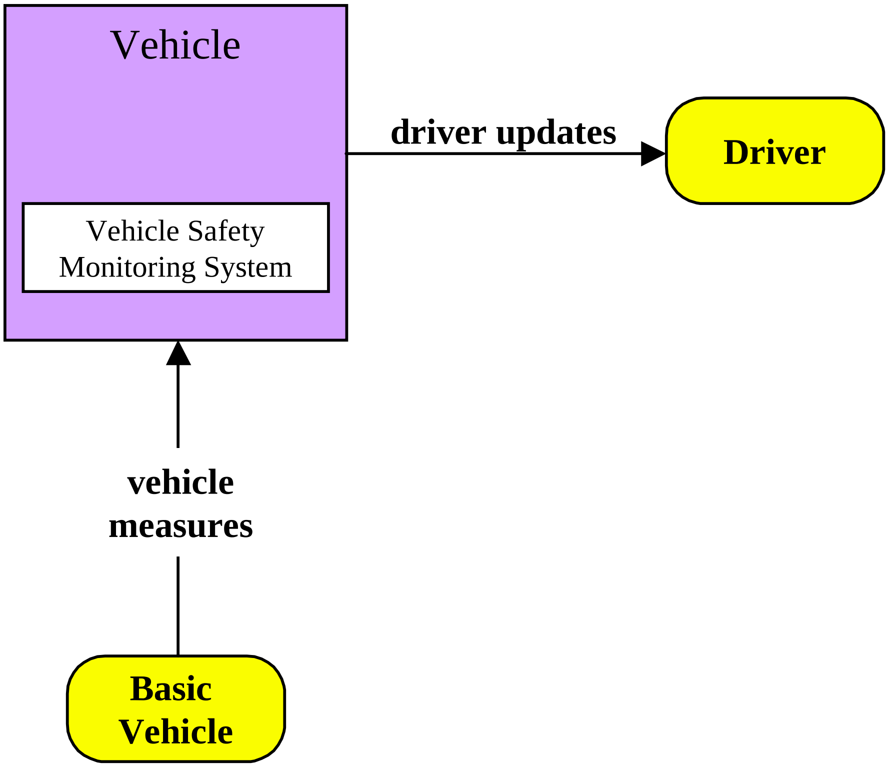
This market package supports distribution of traffic and travel advisory information to drivers through in-vehicle devices. It includes short range communications between roadside equipment and the vehicle and wireline connections to the Traffic Management Subsystem for coordination and control. This market package also informs the driver of both highway-highway and highway-rail intersection status.



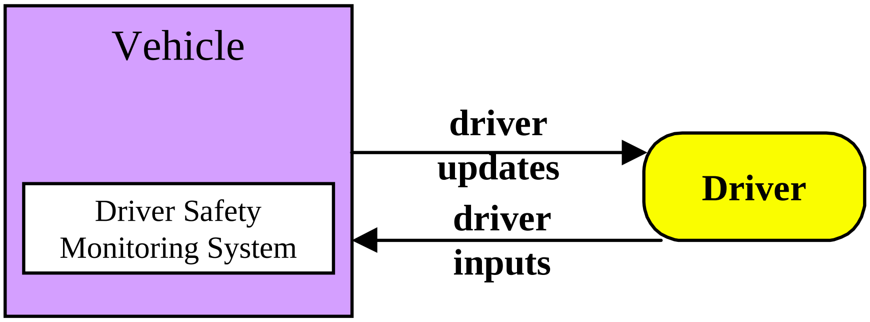
A.4 Advanced Vehicle Safety System Market Packages

Vehicle Safety Monitoring (AVSS1)

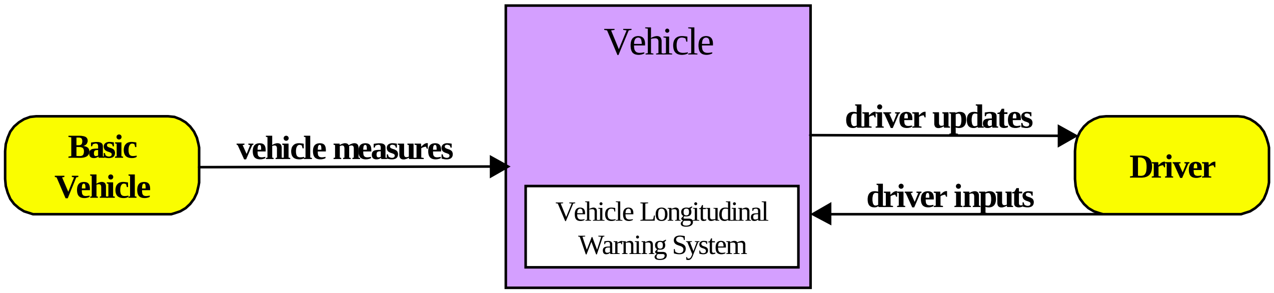
This market package will diagnose critical components of the vehicle and warn the driver of potential dangers. On-board sensors will determine the vehicle's condition and performance, determine on-board safety data and display information.



Driver Safety Monitoring (AVSS2)
This market package will determine the driver's condition, and warn the driver of potential dangers. On-board sensors will determine the driver's condition and performance, determine on-board safety data and display information.

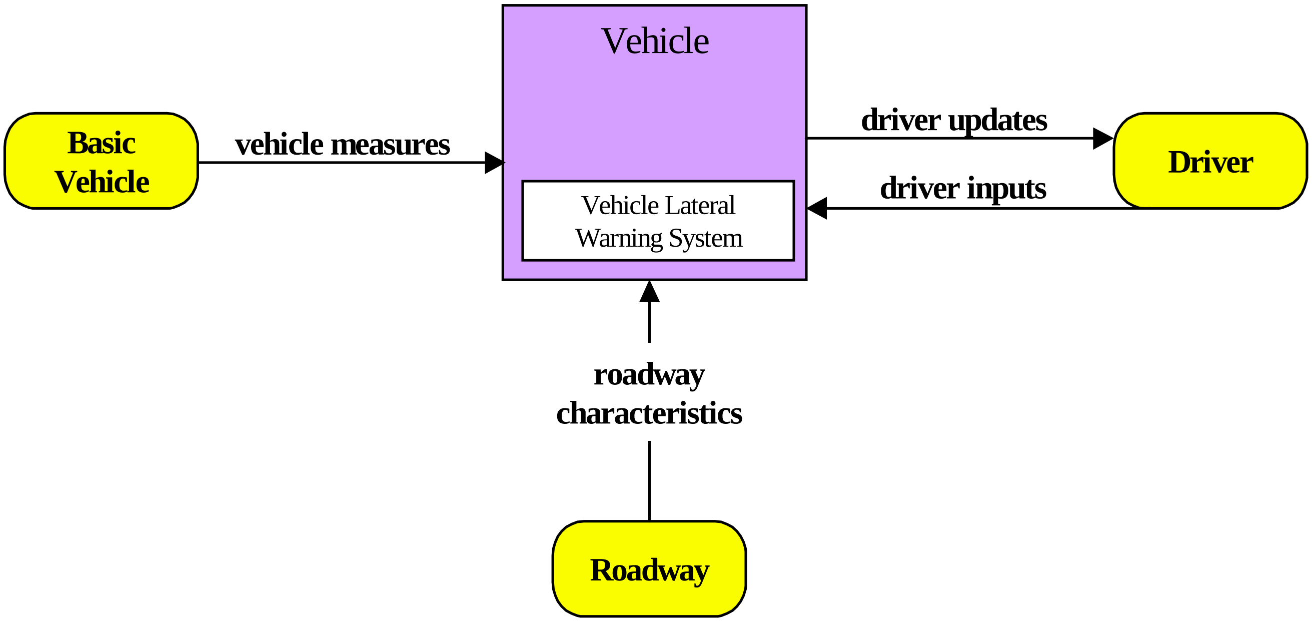


Longitudinal Safety Warning (AVSS3)
This market package allows for longitudinal warning. It utilizes safety sensors and collision sensors. It requires on-board sensors to monitor the areas in front of and behind the vehicle and present warnings to the driver about potential hazards.



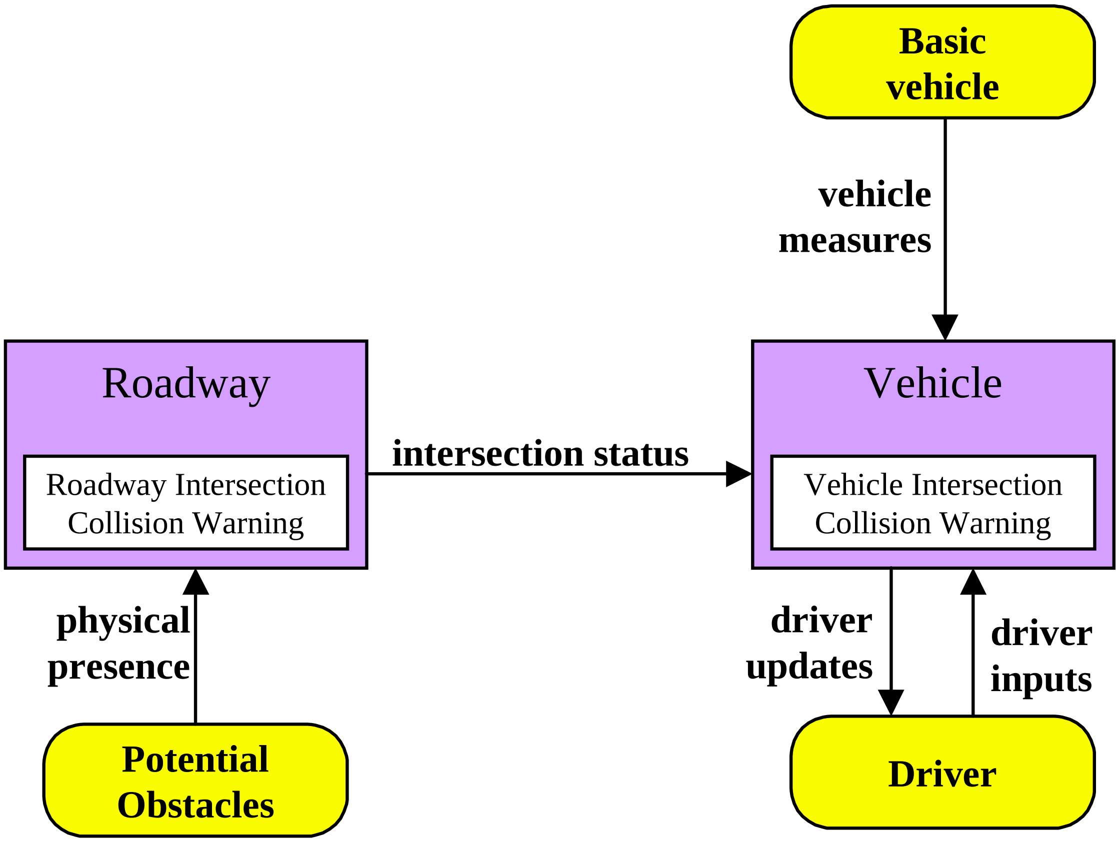
Lateral Safety Warning (AVSS4)

This market package allows for lateral warning. It utilizes safety sensors and collision sensors. It requires on-board sensors to monitor the areas to the sides of the vehicle and present warnings to the driver about potential hazards.



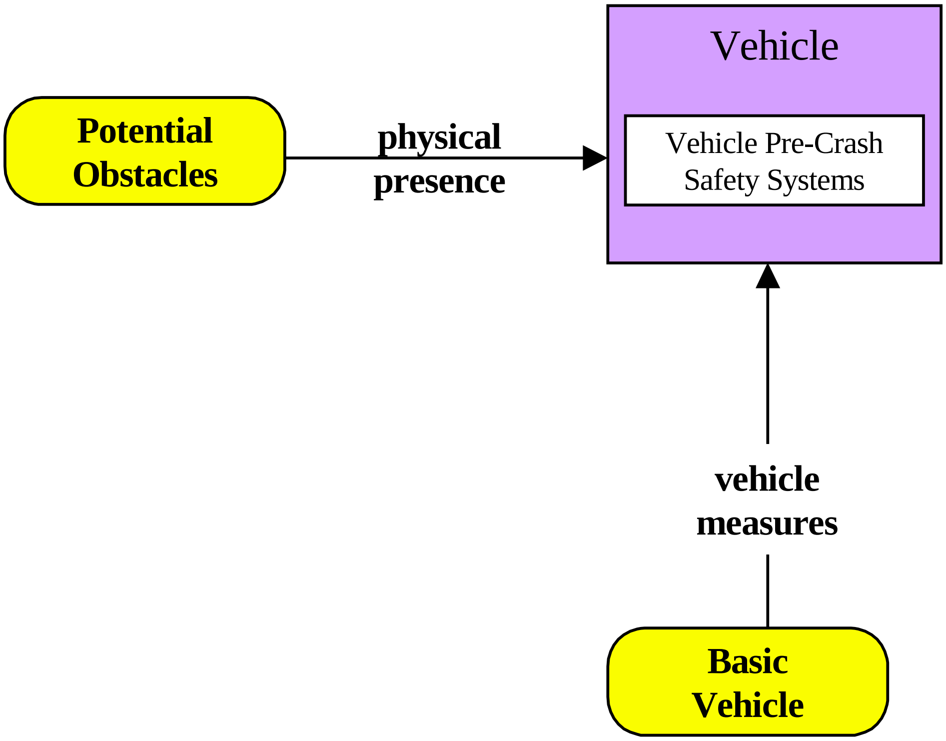
Intersection Safety Warning (AVSS5)

This market package will determine the probability of a collision in an equipped intersection (either highway-highway or highway-rail) and provide timely warnings to drivers in response to hazardous conditions. Monitors in the roadway infrastructure assess vehicle locations and speeds near an intersection. Using this information, a warning is determined and communicated to the approaching vehicle using a short range communications system. Information can be provided to the driver through the market package ATIS9--In-Vehicle Signing.

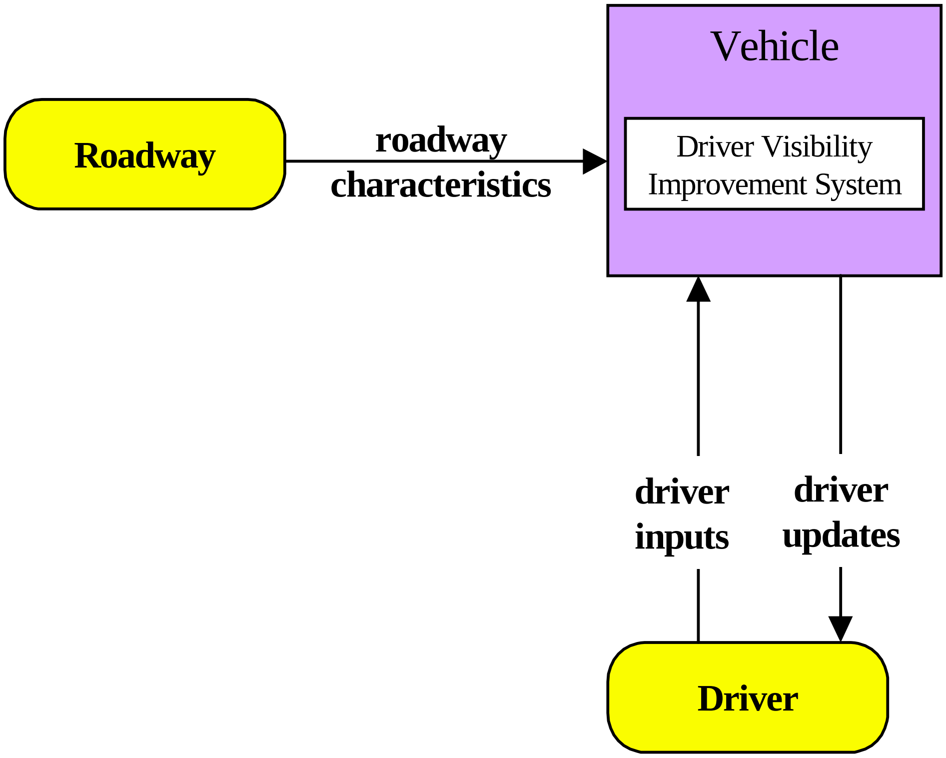


Pre-Crash Restraint Deployment (AVSS6)

This market package provides in-vehicle sensors to monitor the vehicle's local environment, determine collision probability and deploy a pre-crash safety system. It will include on-board sensors to measure lateral and longitudinal gaps and together with weather and roadway conditions will determine lateral and longitudinal collision probability. It will have the mechanism to deploy a pre-crash safety system.

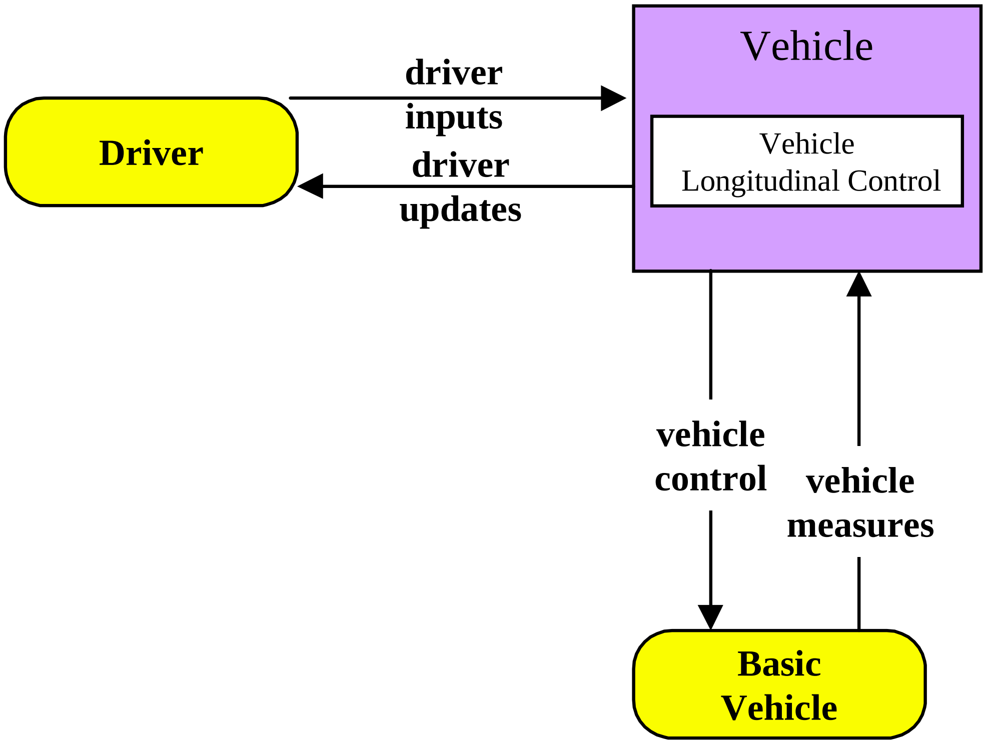


Driver Visibility Improvement (AVSS7)
This market package will enhance driver visibility using an enhanced vision system. On-board display hardware is needed



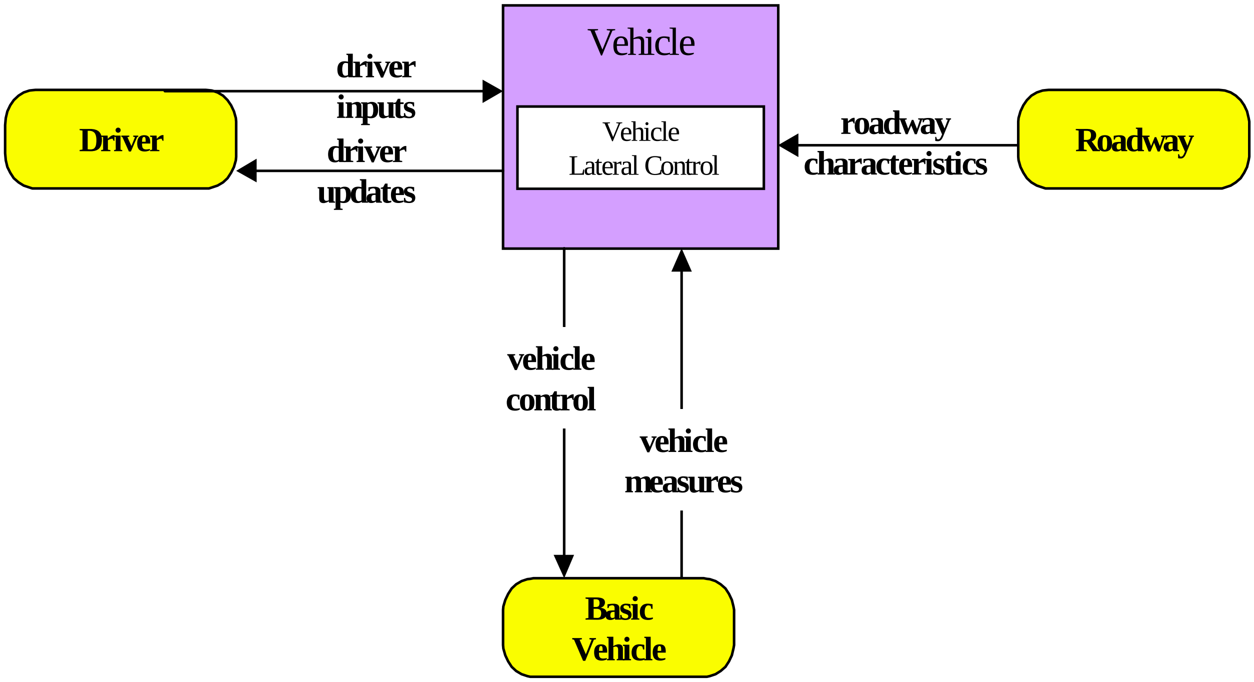
Advanced Vehicle Longitudinal Control (AVSS8)

This market package automates the speed and headway control functions on board the vehicle. It utilizes safety sensors and collision sensors combined with vehicle dynamics processing to control the throttle and brakes. It requires on-board sensors to measure longitudinal gaps and a processor for controlling the vehicle speed.



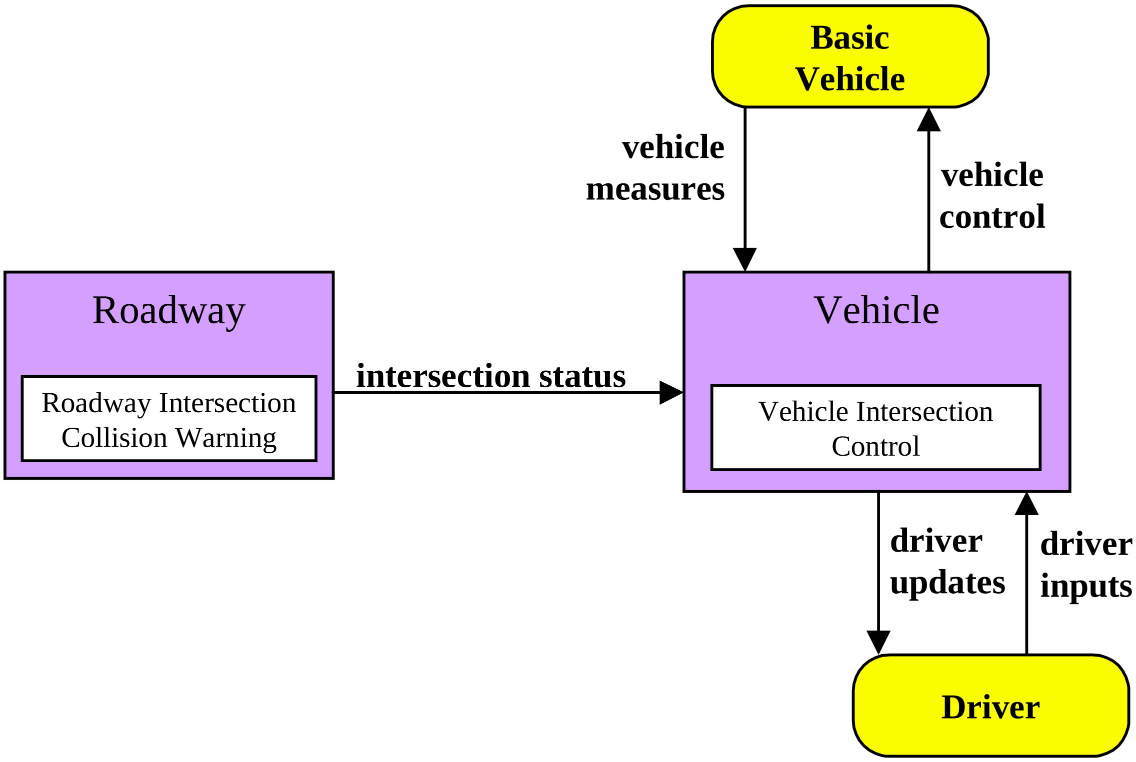
Advanced Vehicle Lateral Control (AVSS9)

This market package automates the steering control on board the vehicle. It utilizes safety sensors and collision sensors combined with vehicle dynamics processing to control the steering. It requires on-board sensors to measure lane position and lateral deviations and a processor for controlling the vehicle steering.



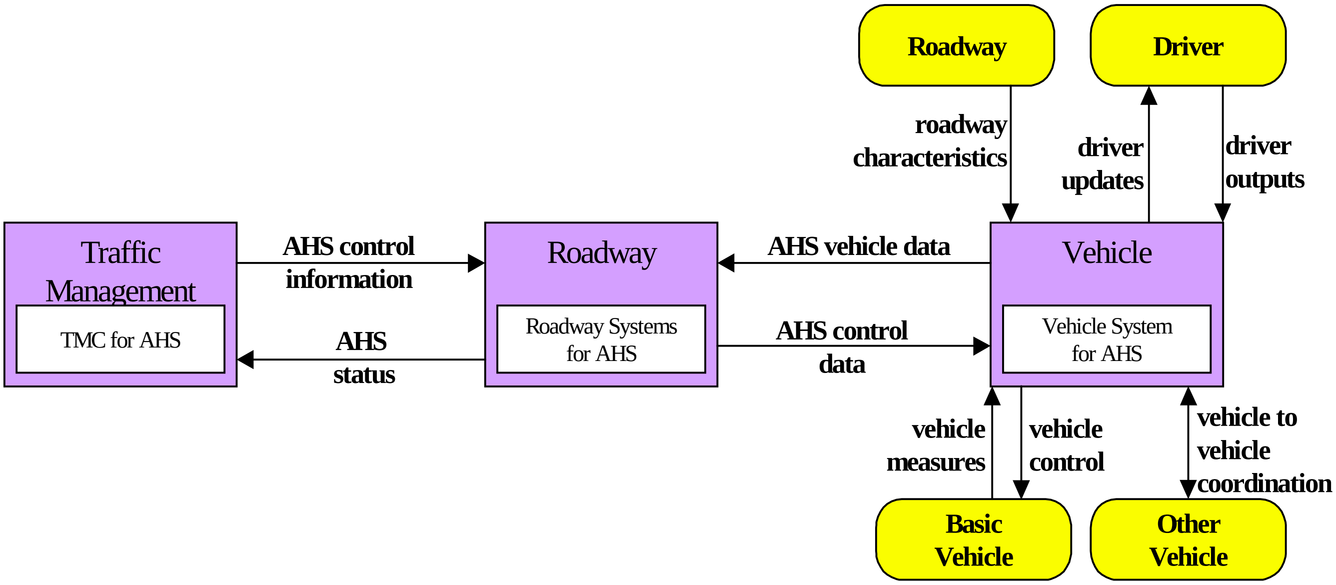
Intersection Collision Avoidance (AVSS10)

This market package will determine the probability of an intersection collision and provide timely warnings to approaching vehicles so that avoidance actions can be taken. This market package builds on the Intersection Collision Warning infrastructure and in-vehicle equipment and adds equipment in the vehicle that can take control of the vehicle in emergency situations. The same monitors in the roadway infrastructure are needed to assess vehicle locations and speeds near an intersection. This information is determined and communicated to the approaching vehicle using a short range communications system. The vehicle uses this information to develop control actions which alter the vehicle's speed and steering control and potentially activate its pre-crash safety system.



Automated Highway System (AVSS11)

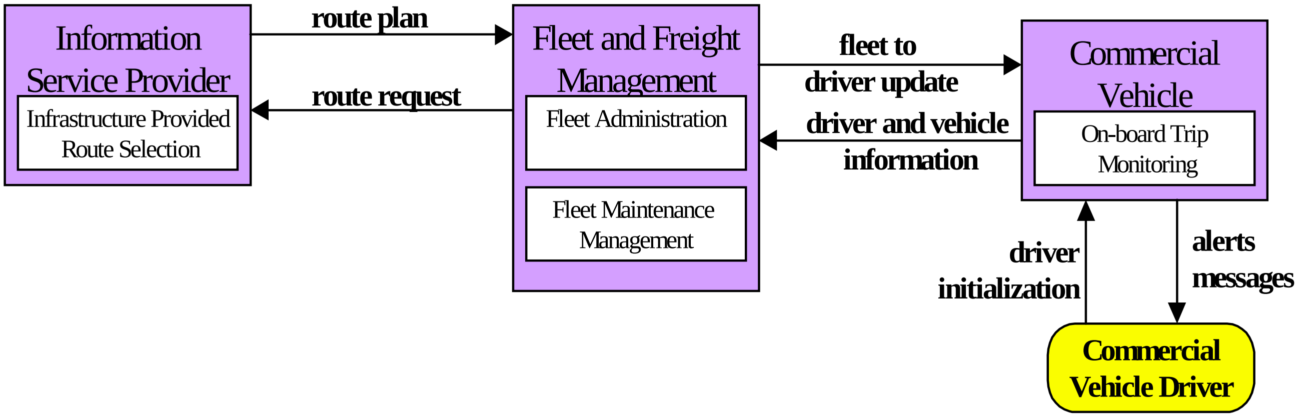
This market package enables "hands-off" operation of the vehicle on the automated portion of the highway system. Implementation requires lateral lane holding, vehicle speed and steering control, and Automated Highway System check-in and checkout. This market package currently supports a balance in intelligence allocation between infrastructure and the vehicle pending selection of a single operational concept by the AHS consortium.



A.5 Commercial Vehicle Operations Market Packages

Fleet Administration (CVO1)

This market package keeps track of vehicle location, itineraries, and fuel usage at the Fleet and Freight Management Subsystem using a cell based or satellite data link and the pre-existing wireless infrastructure. The vehicle has a processor to interface to its sensor (e.g., fuel gauge) and to the cellular data link. The Fleet and Freight Management Subsystem can provide the vehicle with dispatch instructions, and can process and respond to requests for assistance and general information from the vehicle via the cellular data link. The market package also provides the Fleet Manager with connectivity to intermodal transportation providers using the existing wireline infrastructure.

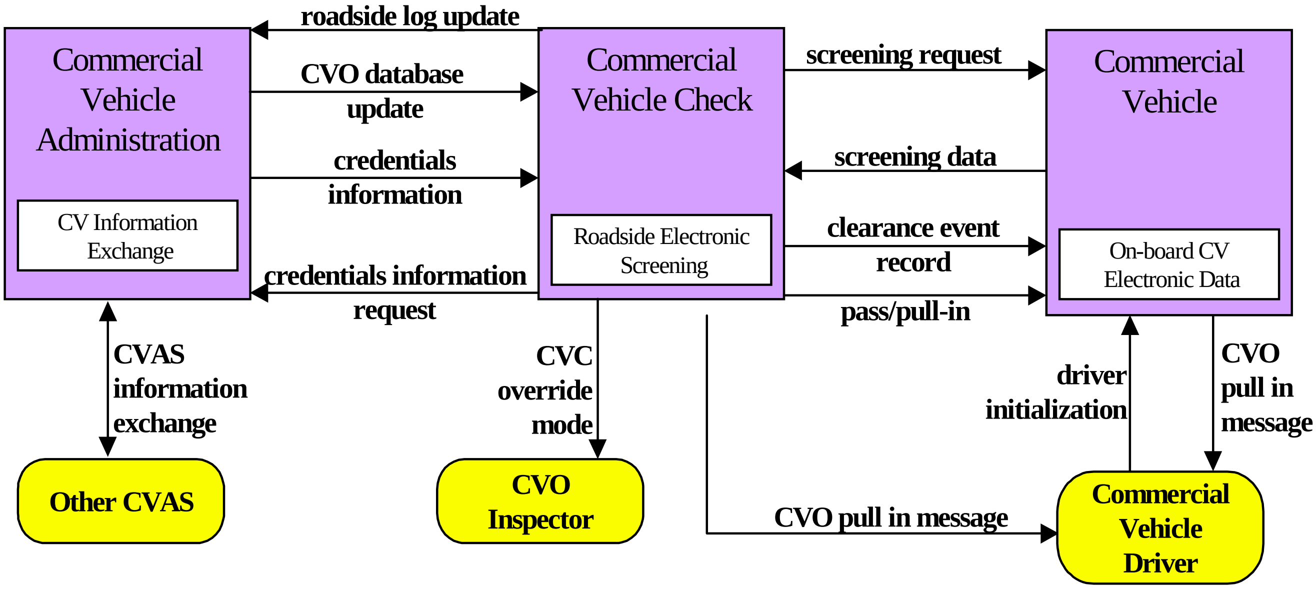


Freight Administration (CVO2)

This market package tracks cargo and the cargo condition. This information is communicated with the Fleet and Freight Management Subsystem via the existing wireless infrastructure. Interconnections are provided to intermodal shippers and intermodal freight depots for tracking the cargo from source to destination.

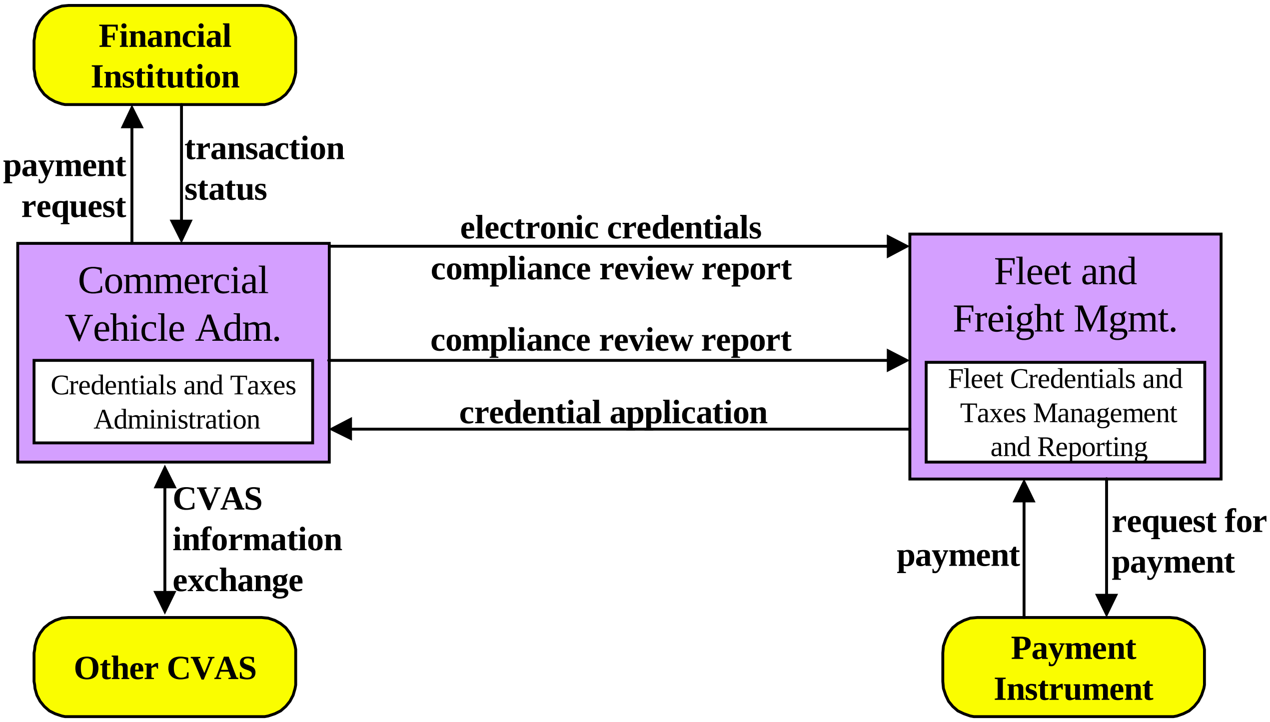
Electronic Clearance (CVO3)

This market package provides for automated clearance at roadside check facilities. The roadside check facility communicates with the Commercial Vehicle Administration subsystem over wireline to retrieve infrastructure snapshots of critical carrier, vehicle, and driver data to be used to sort passing vehicles. This package allows a good driver/vehicle/carrier to pass roadside facilities at highway speeds using transponders and dedicated short range communications to the roadside. The roadside check facility may be equipped with AVI, weighing sensors, transponder read/write devices, computer workstation processing hardware, software, and databases.

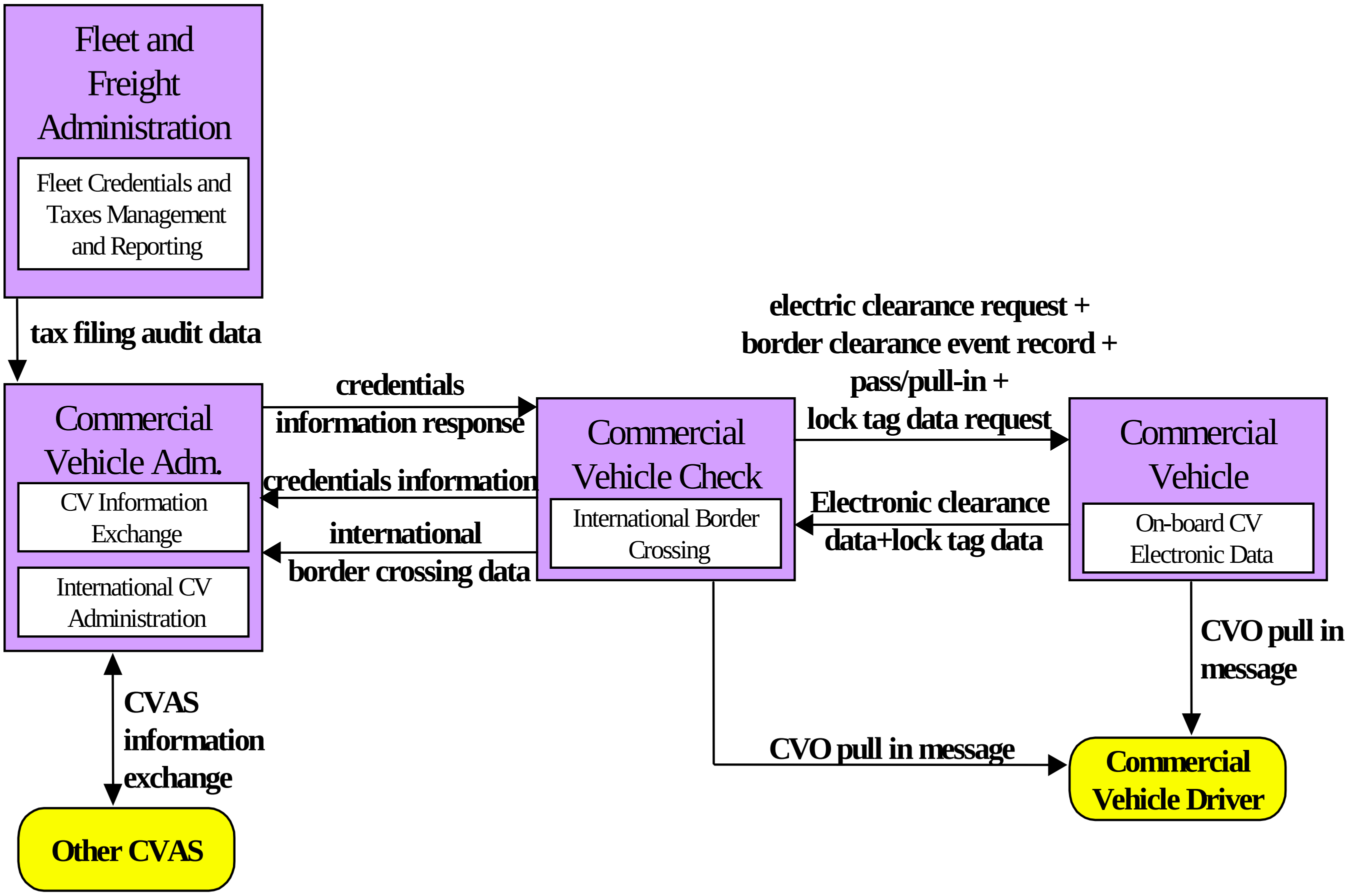


CV Administrative Processes (CVO04)

This market package provides for electronic application, processing, fee collection, issuance, and distribution of CVO credential and tax filing. Through this process, carriers, drivers, and vehicles may be enrolled in the electronic clearance program provided by a separate market package which allows commercial vehicles to be screened at mainline speeds at commercial vehicle check points. Through this enrollment process, current profile databases are maintained in the Commercial Vehicle Administration Subsystem and snapshots of this database are made available to the commercial vehicle check facilities at the roadside to support the electronic clearance process.

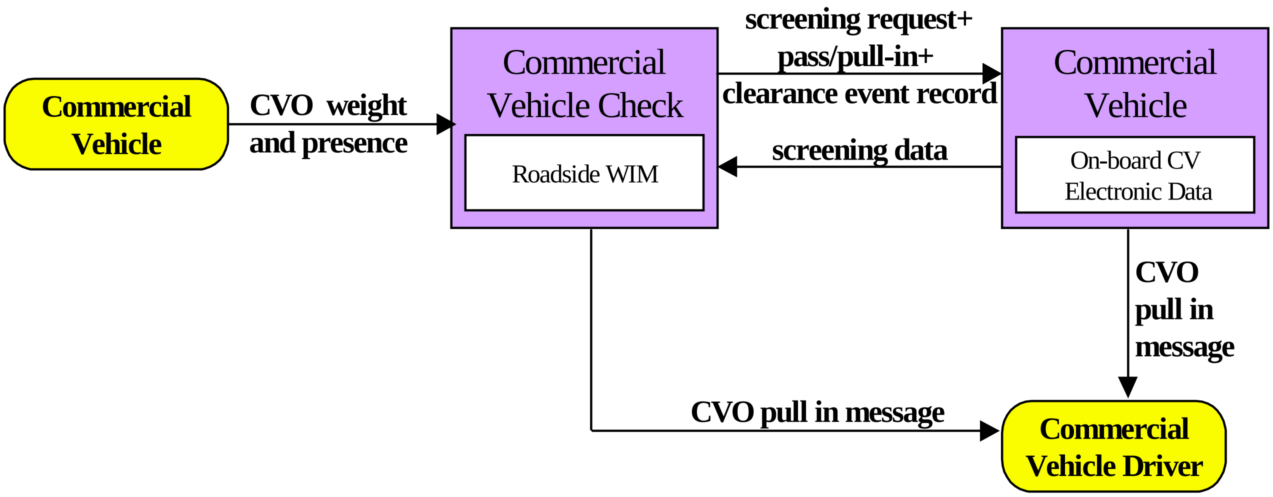


International Border Electronic Clearance (CVO05)
This market package provides for automated clearance specific to international border crossings. This package augments the electronic clearance package by allowing interface with customs related functions and permitting NAFTA required entry and exit from the US to Canada and Mexico.



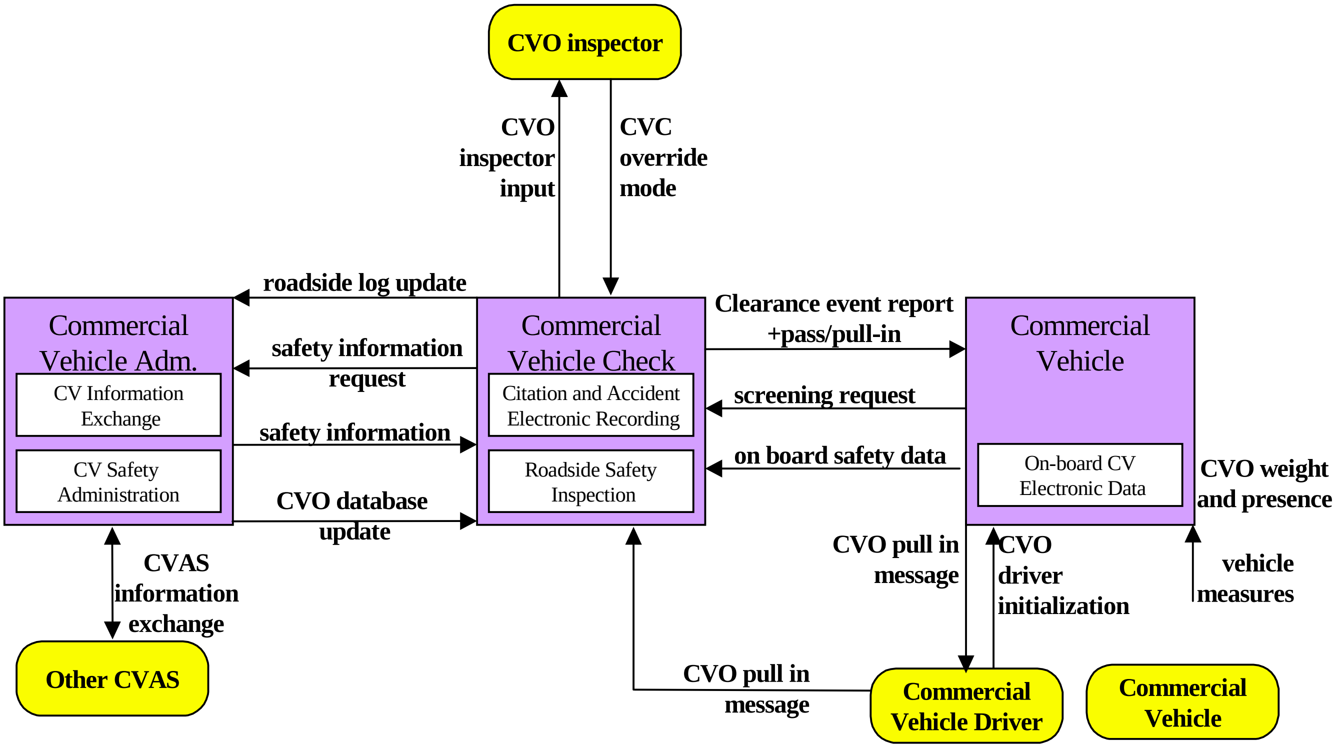
Weigh-In-Motion (CVO06)

This market package provides for high speed weigh-in-motion with or without AVI attachment. Primarily this market package provides the roadside with additional equipment, either fixed or removable. If the equipment is fixed, then it is thought to be an addition to the electronic clearance and would work in conjunction with the AVI and AVC equipment in place.



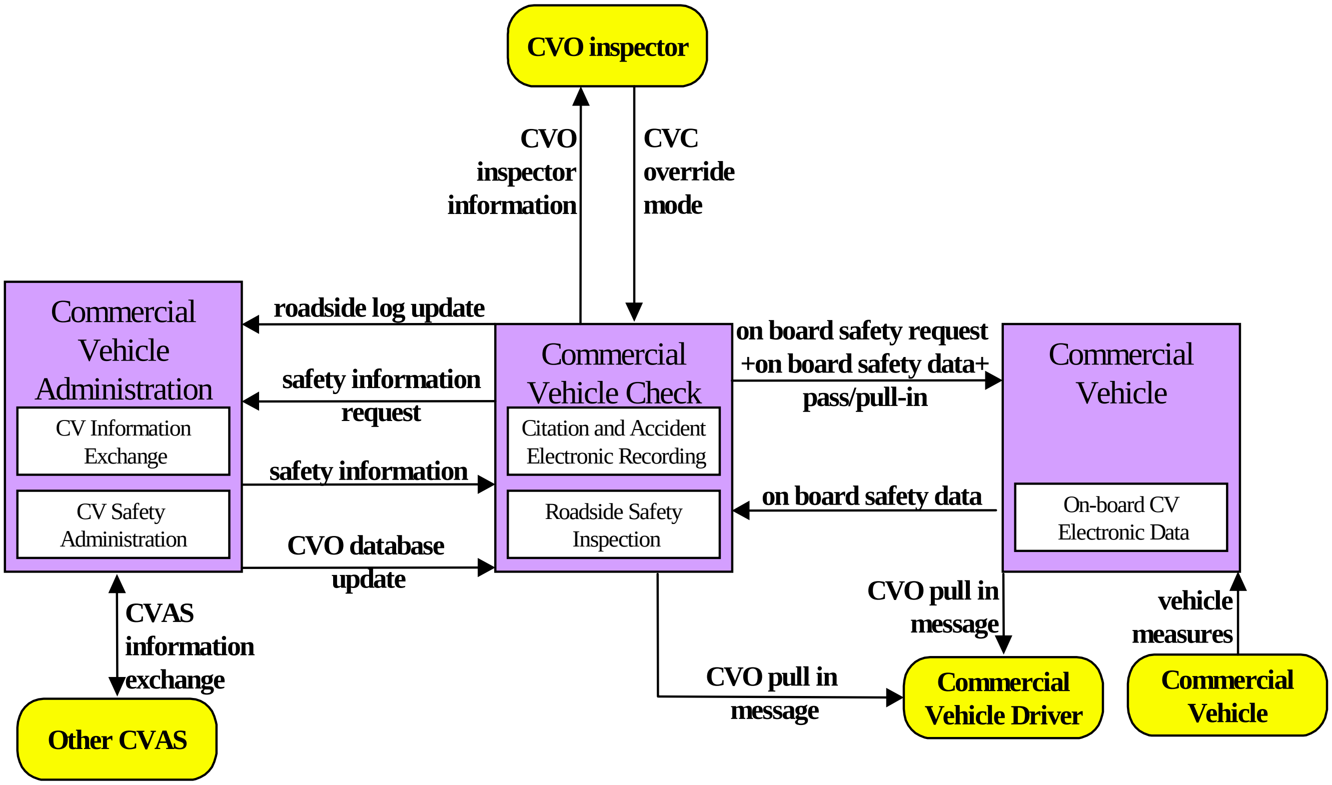
Roadside CVO Safety (CVO07)

This market package provides for automated roadside safety monitoring and reporting. It automates commercial vehicle safety inspections at the Commercial Vehicle Check roadside element. The capabilities for performing the safety inspection are shared between this market package and the On-Board CVO Safety Market Package which enables a variety of implementation options. The basic option, directly supported by this market package, facilitates safety inspection of vehicles that have been pulled in, perhaps as a result of the automated screening process provided by the Electronic Clearance Market Package. In this scenario, only basic identification data and status information is read from the electronic tag on the commercial vehicle. The identification data from the tag enables access to additional safety data maintained in the infrastructure which is used to support the safety inspection, and may also inform the pull-in decision if system timing requirements can be met. More advanced implementations, supported by the On-Board CVO Safety market package, utilize additional vehicle safety monitoring and reporting capabilities in the commercial vehicle to augment the roadside safety check.



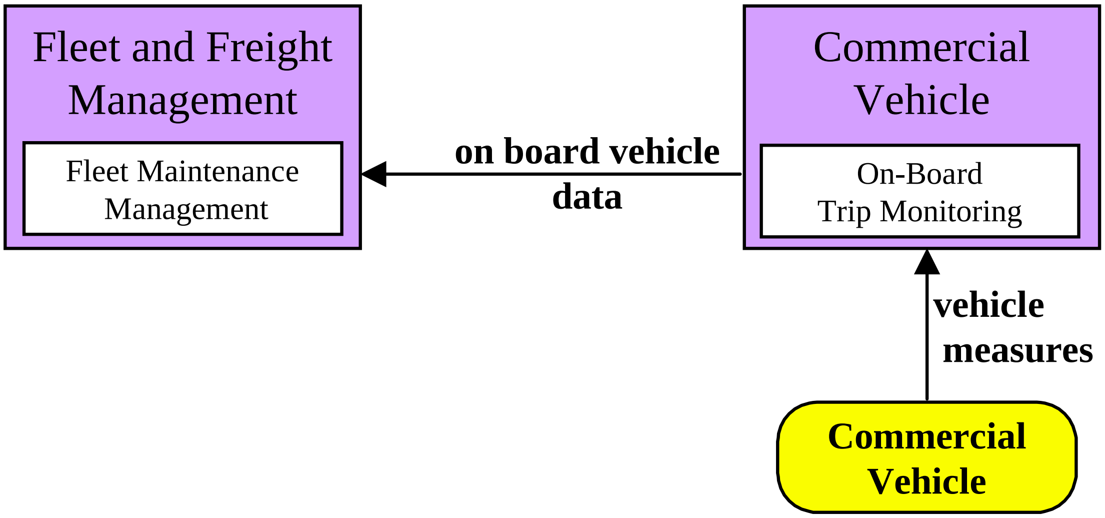
On-board CVO Safety (CVO08)

This market package provides for on-board commercial vehicle safety monitoring and reporting. It is an enhancement of the Roadside CVO Safety Market Package and includes roadside support for reading on-board safety data via tags. This market package uses the same communication links as the Roadside CVO Safety Market Package, and provides the commercial vehicle with a wireless link (data and possibly voice) to the Fleet and Freight Management and the Emergency Management Subsystems. Safety warnings are provided to the driver as a priority with secondary requirements to notify the Fleet and Freight Management and Commercial Vehicle Check roadside elements.



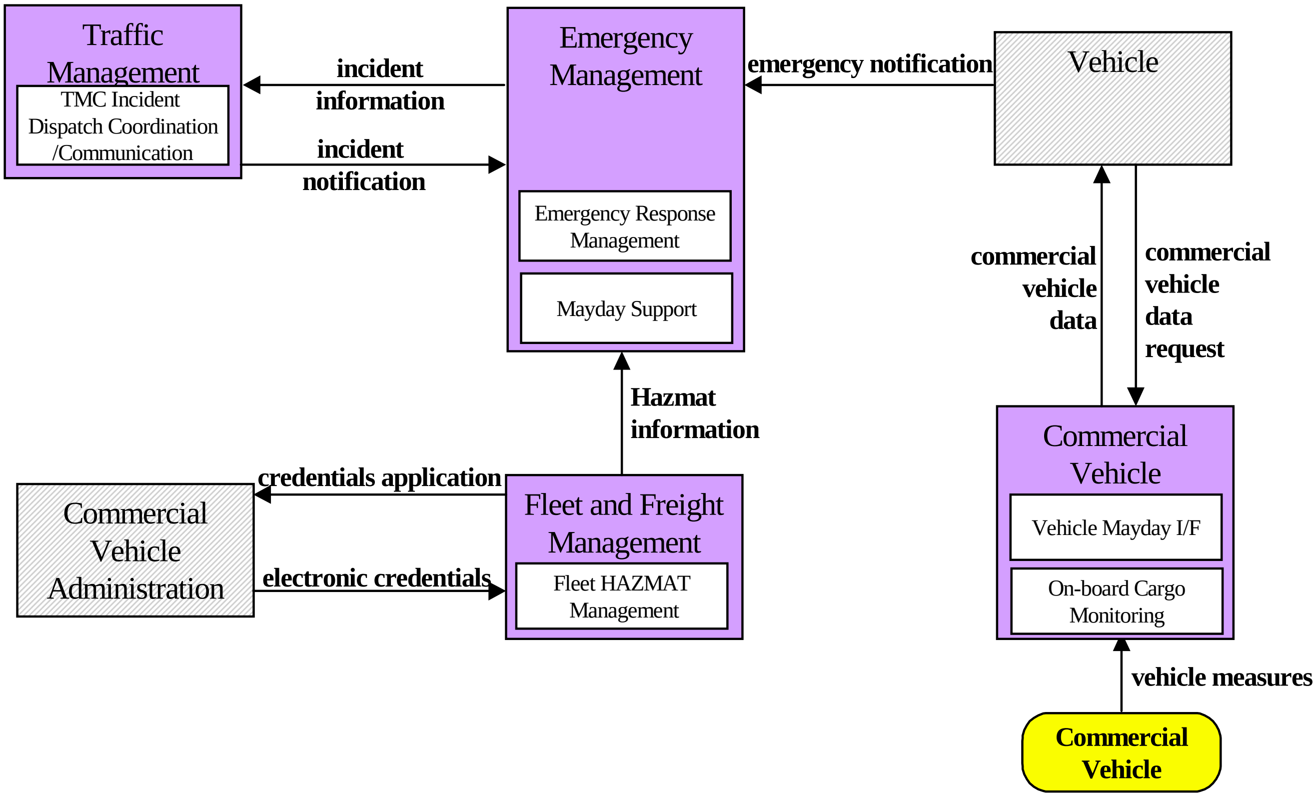
CVO Fleet Maintenance (CVO09)

This market package supports maintenance of CVO fleet vehicles through close interface with on-board monitoring equipment and AVLS capabilities with in the Fleet and Freight Management Subsystem. Records of vehicle mileage, repairs, and safety violations are maintained to assure safe vehicles on the highway.



HAZMAT Management (CVO10)

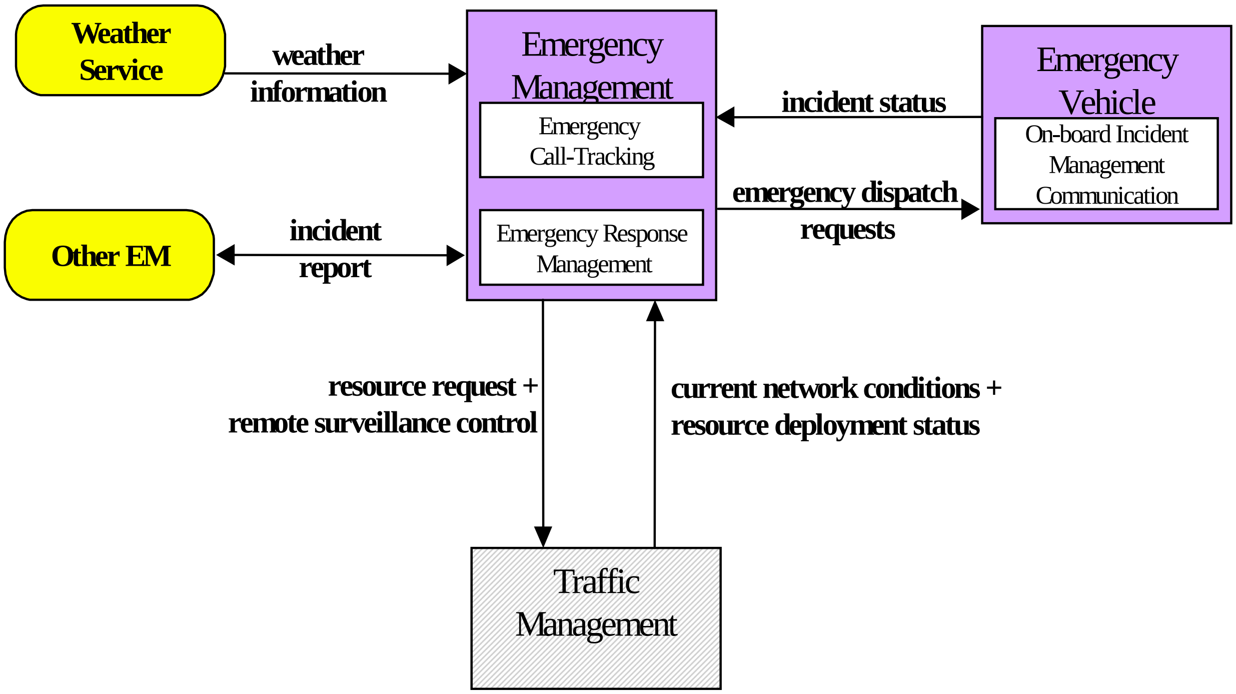
This market package integrates incident management capabilities with commercial vehicle tracking to assure effective treatment of HAZMAT material and incidents. HAZMAT tracking is performed by the Fleet and Freight Management Subsystem. The Emergency Management subsystem is notified by the Commercial Vehicle if an incident occurs and coordinates the response. The response is tailored based on information that is provided as part of the original incident notification or derived from supplemental information provided by the Fleet and Freight Management Subsystem. The latter information can be provided prior to the beginning of the trip or gathered following the incident depending on the selected policy and implementation.



A.6 Emergency Management Market Packages

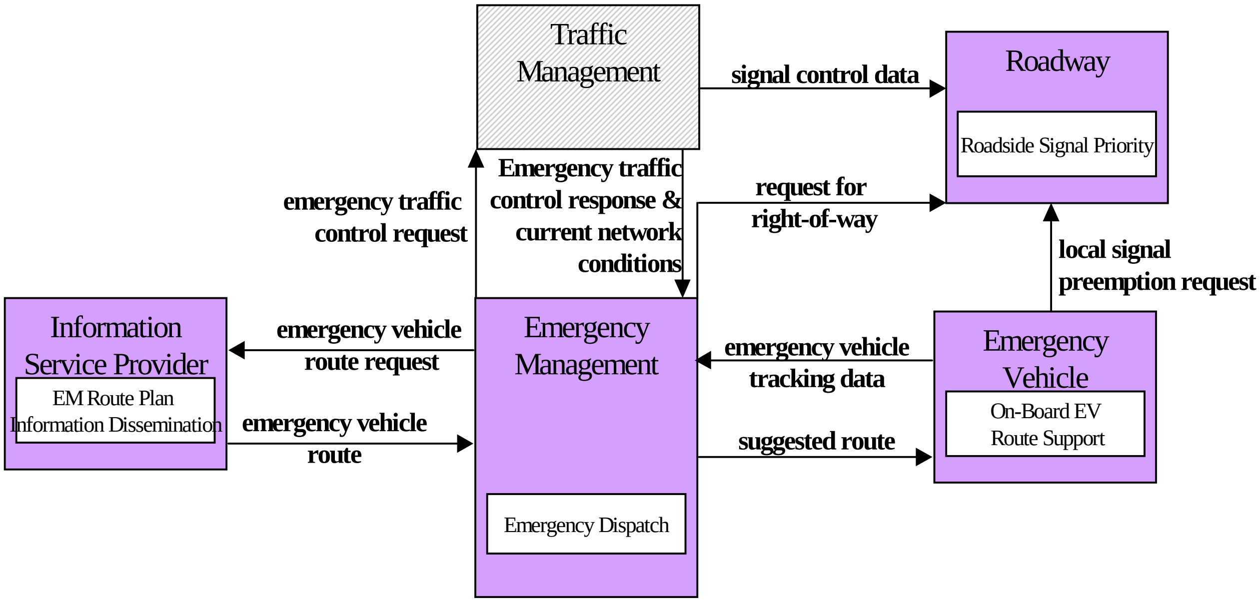
Emergency Response (EM1)

This market package provides the computer-aided dispatch systems, emergency vehicle equipment, and wireless communications that enable safe and rapid deployment of appropriate resources to an emergency. Coordination between Emergency Management Subsystems supports emergency notification and coordinated response between agencies. Existing wide area wireless communications would be utilized between the Emergency Management Subsystem and an Emergency Vehicle to enable an incident command system to be established and supported at the emergency location. The Emergency Management Subsystem would include hardware and software for tracking the emergency vehicles. Public safety, traffic management, and many other allied agencies may each participate in the coordinated response managed by this package.



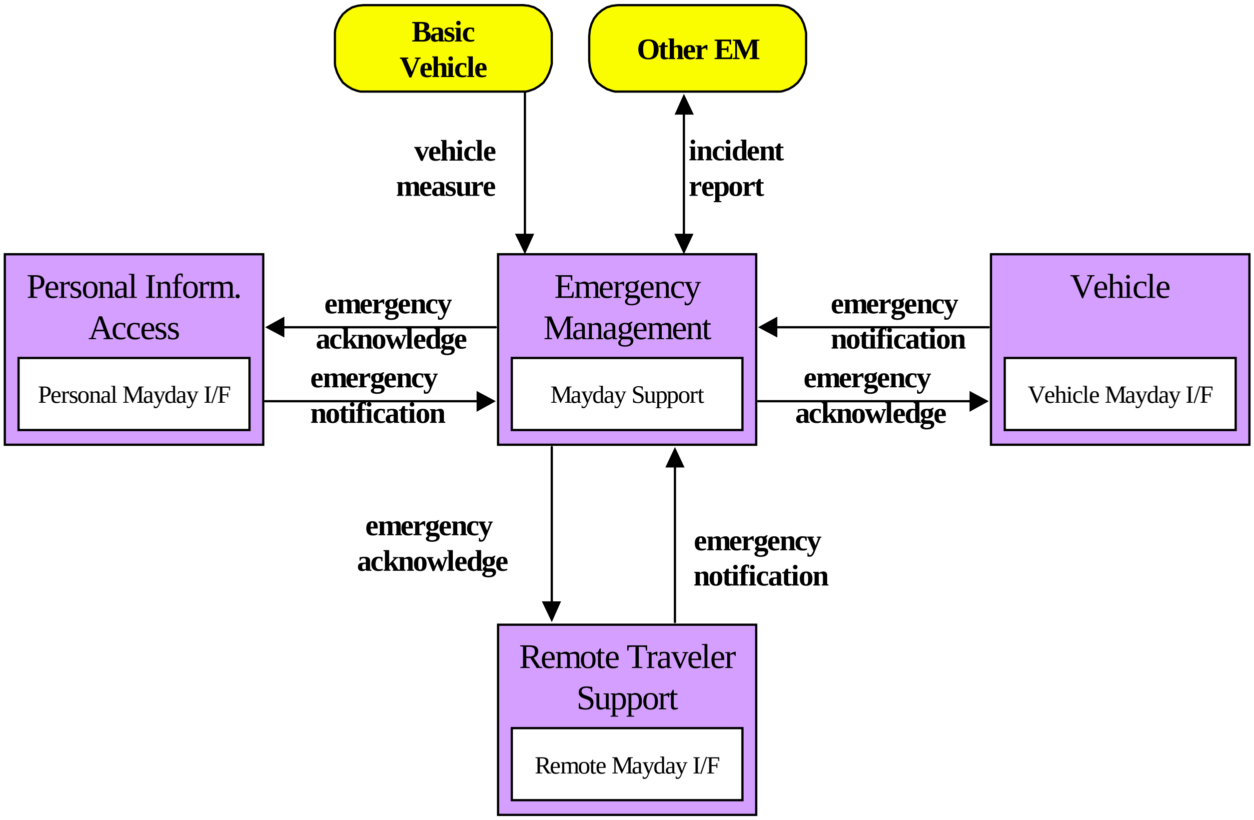
Emergency Routing (EM2)

This market package supports dynamic routing of emergency vehicles and coordination with the Traffic Management Subsystem for special priority on the selected route(s). The Information Service Provider Subsystem supports routing for the emergency fleet based on real-time traffic conditions and the emergency routes assigned to other responding vehicles. In this market package, the Information Service Provider Subsystem would typically be integrated with the Emergency Management Subsystem in a public safety communications center. The Emergency Vehicle would also optionally be equipped with dedicated short range communications for local signal preemption.



Mayday Support (EM3)

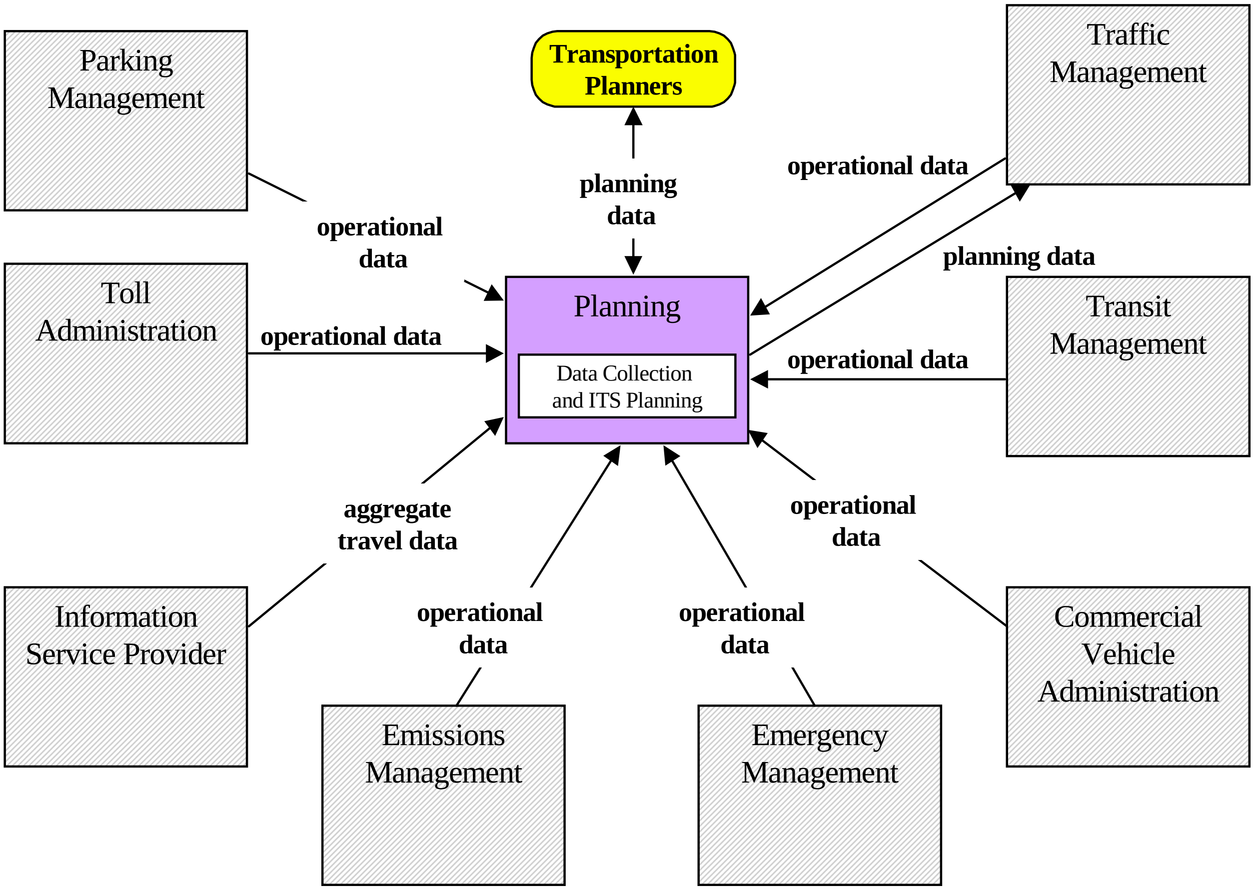
This package allows the user (driver or non-driver) to initiate a request for emergency assistance and enables the Emergency Management Subsystem to locate the user and determine the appropriate response. The Emergency Management Subsystem may be operated by the public sector or by a private sector provider. The request from the traveler needing assistance may be manually initiated or automated and linked to vehicle sensors. The data is sent to the Emergency Management subsystem using wide area wireless communications with voice as an option. Providing user location implies either a location technology within the user device or location determination within the communications infrastructure.



A.7 ITS Planning Market Package

ITS Planning (ITS1)

This market package supports ITS planning functions. It accepts data from every center subsystem and uses this data to plan new deployments. This data also supports policy decision making, allocation of funding, allocation of resources and other planning activities..



Appendix B : Market Package Deployment Timing

The level of deployment for each market package is estimated in this section for three selected time frames and three geographic settings based on underlying technical constraints, assumptions, institutional issues, and strategic priorities described in the body of the Implementation Strategy.

It should be noted that the material in this section is a forecast rather than a "strategy". The ITS architecture does not restrict deployment to the sequence depicted in this section. Rather, it supports a range of deployment sequences that might be used to develop infrastructures to support ITS deployments that are tailored to meet local needs. It provides interface standards and guidelines to ensure complete interoperability across all ITS deployments.

To develop the forecast, each market package was analyzed with regard to the influences identified in Section 2.7 to estimate its expected deployment. This section provides a summary of the analyses for each defined market package to illustrate the technical and non-technical considerations that influence the selected deployment sequence. For each market bundle, two tables are shown. The first summarizes the expected deployment for that bundle over the 5, 10, and 20 year time frames; the second summarizes near-term influences on deployment.

The deployment estimates that are made in this section are deliberately qualitative and somewhat independent of an absolute estimate of market penetration. The qualitative estimates reflect the large degree of uncertainty inherent in any projections of formative markets like ITS. Three general stages of deployment are presented in the tables for each market package:

> Initial deployment -- when a market package first exists in an operational setting. The key word is operational -- the package is not experimental or a demonstration project. Moreover, the financial and institutional structures are operational as well, e.g., funding responsibilities are being borne by the individuals/groups in the way that is designed for the life of the system, not just the start-up period.
>
> Threshold deployment -- is a level of deployment that triggers a new level of service quality or the introduction of a new service component. Deployment thus incorporates market penetration, that is, the service is actually used rather than just available. Threshold deployment is the minimal level of deployment for efficient operation of that market package and may also constitute the minimal level of deployment for efficient operation of a related package (as a result of interdependencies).
>
> Full deployment -- is achieved when there is widespread usage of that market package well in excess of threshold conditions to achieve system efficiency.

B.1 Advanced Traffic Management Systems (ATMS)

The implementors of ATMS will be primarily public agencies that own and operate streets and roads. ATMS will be deployed more extensively in congested urban areas than in either inter-urban areas or rural areas because there is more traffic in urban areas and therefore more need for traffic management and more opportunity to use alternate routes or modes.. The architecture supports several different packages for instrumentation of the roadways and control of traffic.

Some network surveillance and centralized street and freeway signal control has already been initiated in many large cities and congested suburbs. It is expected that this will expand rapidly. Such facilities will be longer in coming on inter-urban roads, and may never be needed in rural areas unless they have high volumes of through traffic, special events, or resort traffic.

Surveillance is a necessary prerequisite to incident detection and management, traffic information dissemination, network performance evaluation, and traffic system maintenance. Once surveillance is established in neighboring jurisdictions, information can be shared, and signal control, freeway control, and incident management can be coordinated.

Table B.1-1: ATMS Deployment Profile

Advanced Traffic Management Systems	**Deployment Scenarios**								
	5-year			10-year			20-year		
	Urban	Inter-urban	Rural	Urban	Inter-urban	Rural	Urban	Inter-urban	Rural
Network Surveillance	❍			⬤			⬤		
Probe Surveillance	•			❍	•		⬤	❍	
Surface Street Control	❍			⬤			⬤		
Freeway Control	•			❍	•		⬤	❍	
HOV and Reversible Lane Management	•			❍	•		⬤	❍	
Traffic Information Dissemination	•			❍	•	•	⬤	❍	•
Regional Traffic Control	•			❍	•		⬤	❍	•
Incident Management System	•			❍	•		⬤	❍	
Traffic Network Performance Evaluation	•			❍	•		⬤	❍	
Dynamic Toll/Parking Fee Management	•	•		❍	❍		⬤	⬤	
Emissions and Environmental Hazards Sensing	•			❍	•		⬤	•	
Virtual TMC and Smart Probe Data						•			❍
Standard Railroad Grade Crossing	❍	•		⬤	❍	•	⬤	⬤	❍
Advanced Railroad Grade Crossing				•	•		❍	❍	
Railroad Operations Coordination				•			❍	•	

Legend • :Initial Deployment ❍ :Threshold Deployment ⬤ :Full Deployment

Table B.1-2 Influences on Near Term ATMS Deployment

Market Package	Deployment Depends on:	Timing Considerations	Incentives to Deployment
Network Surveillance	• NTCIP standard for traffic control and sensing devices	• Near Term	Collection of reliable traffic data
Probe Surveillance	• Wide area communications equipment in-vehicle.	• Currently available but depends on other package deployments	Collection of reliable traffic data
Surface Street Control	• NTCIP standard for traffic control and sensing devices	• Near term	Improved utilization of surface streets
Freeway Control	• Public support for potential reduction in individual convenience to gain overall improvement in efficiency.	• Requires continued ATMS sales job to public	Improved utilization of freeways
HOV and Reversible Lane Management	• NTCIP control standards • HOV violation detection algorithms	• NTCIP is near term • Algorithms are a long way ahead	Better traveler utilization of existing freeways
Traffic Information Dissemination	• Traffic information standard	• NTCIP may branch out to cover this standard • May be covered by ATIS standards	Allows travelers to select less congested route or change plans in case of unexpected delays
Regional Traffic Control	• Freeway and surface street control	• Will follow freeway and street control	Reduced overall delay
Incident Management System	• Better surveillance and algorithms • Emergency management standards • Coordination plans	• Surveillance and algorithms are currently becoming available • Some standards are underway	Automated incident detection reduces incident clearing time and reduces congestion and can reduce negative consequences of injuries
Traffic Network Performance Evaluation	• Surveillance • Traffic Models	• Surveillance package • Algorithms are current area of research	Improved prediction of travel times
Dynamic Toll/Parking Fee Management	• VRC technology • Development of payment system		Reduced toll and fee collection costs Greater convenience
Emissions and Environmental Hazards Sensing	• Emissions sensing equipment • NTCIP standards	• Regulations will accelerate deployment	Cleaner environment
Virtual TMC and Smart Probe Data	• In-vehicle sensors • Wide Area Comm. in rural areas	• Wide Area Comm. is increasing rapidly in rural areas	Greater safety and better trip planning
Standard Railroad Grade Crossing	• Public support for potential improvement in safety.	• Parallels surface street control enhancements	Increased Safety at HRI

Market Package	Deployment Depends on:	Timing Considerations	Incentives to Deployment
Advanced Railroad Grade Crossing	• Public interest in high-speed rail transit	• Technology dependent • Public acceptance for long closure times	Improved efficiency in rail transit system Increased Safety at HRI
Railroad Operations Coordination	• Communications between Railroad Operations Centers (ROC) , TMCs, and DOTs	• Implementation of regional traffic control strategies	Reduced overall delay

B.2 Advanced Public Transportation Systems (APTS)

Users of these services will be public transit agencies. Services such as transit security, electronic fare collection, and improved information, will have a direct effect on transit use. Other services may improve service or reduce costs, thus allowing operators to provide more service or charge lower fares than would otherwise be possible. There are no significant technical barriers to implementation, but some services may not provide sufficient benefits over current, less communication-intensive services, to justify the additional cost.

Table B.2-1 APTS Deployment Profile

Advanced Public	**Deployment Scenarios**								
Transit Systems	5-year			10-year			20-year		
	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural	Urban	Inter-Urbar	Rural
Transit Vehicle Tracking									
Transit Fixed Route Operations									
Demand Response Transit Operations									
Transit Passenger and Fare Management									
Transit Security									
Transit Maintenance									
Multi-Modal Coordination									
Legend		:Initial Deployment			:Threshold Deployment			:Full Deployment	

Table B.2-2 Influences on Near Term APTS Deployment

Market Package	Deployment Depends on	Timing Considerations	Incentives to Deployment
Transit Vehicle Tracking	• Capacity on Wide Area Private communication channels	• Wait for current equipment to become obsolete	More efficient tracking of buses and recording of schedule adherence
Transit Fixed Route Operations	• Cost advantage of more technically advanced systems over current systems	• Federal funding for new systems	Better scheduling and utilization of resources
Demand Response Transit	• Vehicle tracking, scheduling, and dispatch capability • Passenger Security	• Will come with tracking market package • Will come with transit security	Integrated and personalized dynamic service
Passenger and Fare Management	• Payment Instrument Standard	• Development of sensors and SmartCard Standards	Increased convenience for passengers Reduced fare handling and patronage reporting costs
Transit Security	• Technology to detect incidents • Standard Mayday Interface • Perceived effect of technology on passenger and driver safety	• Mayday interface may come from Mayday Market Package	Increased passenger and operator safety

Market Package	Deployment Depends on	Timing Considerations	Incentives to Deployment
Transit Maintenance	• On board diagnostics	• Benefits of on-board diagnostics not clear	Improved scheduling and monitoring increase reliability and reduce equipment costs
Multi-Modal Coordination	• Inter-agency agreements • Inter-agency exchange of Information	• No technology issues. • Need standard defined between transportation entities	Transit vehicle priority can reduce travel time for passengers Connecting vehicles can be held at transfer points to accommodate passengers transferring from delayed vehicles

B.3 Advanced Traveler Information Systems (ATIS)

Broadcast-based ATIS is now available in many areas via conventional radio, cable TV and limited-range, highway advisory radio. Fixed and portable variable message signs on roads and streets provide information related to safety, delays, and recommended routing. Services, such as these, which assist road management are likely to be deployed in the near term.

Services purchased by travelers are also available. In-vehicle route guidance devices are especially useful to travelers in unfamiliar areas. Although they are relatively expensive, many people may find them cost-effective on rental cars. In-vehicle ATIS deployment will be driven primarily by public demand for travel information.

Table B.3-1 ATIS Deployment Profile

Information Systems	5-year			10-year			20-year		
	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural
Broadcast Traveler Information									
Interactive Traveler Information									
Autonomous Route Guidance									
Dynamic Route Guidance									
ISP Based Route Guidance									
Integrated Transportation Management/Route Guidance									
Yellow Pages and IReservation									
Dynamic Ridesharing									
In Vehicle Signing									
Legend		:Initial Deployment			:Threshold Deployment			:Full Deployment	

Table B.3-2 Influences on Near Term ATIS Deployments

Market Package	Deployment Depends on	Timing Considerations	Incentives to Deployment
Broadcast Traveler Information	• Traffic information	• Already provided	Demonstrated demand for such information
Interactive Traveler Information	• Quality traffic information • Position determination, map database standards	• Surveillance market package • Current trials indicate some interest	Improved trip and activity planning
Autonomous Route Guidance	• Map data base • Vehicle location system	• Currently available but expensive	More useful and convenient than map
Dynamic Route Guidance	• Quality traffic information • Algorithms for selecting optimal routes for individuals	• Algorithms not yet developed	Reduced travel time
ISP Based Route Guidance	• Quality traffic information • Algorithms for selecting optimal routes for individuals	• Algorithms not yet developed	Reduced travel time
Integrated Transportation Management/Route Guidance	• Quality traffic information • Algorithms for selecting optimal system route assignments • Public acceptance of benefits of recommended routes	• Algorithms for optimizing large systems not developed	Reduced overall delay
Yellow Pages and Reservations	• Industry willing to pay for service • Clients with need and in-vehicle equipment	• Will come with demonstrated success • Depends on deployment of Wide-area communication in-vehicle equipment	Greater traveler convenience Increased patronage for businesses using the service
Dynamic ridesharing	• High concentrations of trips with the same origins and destinations	• Declining proportion of travelers ridesharing	Reduced travel expenses Environmental benefits
In-vehicle Signing	• Low cost for transmission of information from roadside and for in-vehicle reception and display	• Duplicates an existing service (roadside signs)	Provides information when visibility of roadside is poor

B.4 Advanced Vehicle Safety Systems (AVSS)

Most AVSS market packages well be purchased as components of new vehicles. Therefore, the pace of their deployment will be dictated by the cost and demand for such systems. Because only six to seven percent of the vehicle fleet is composed of new vehicles each year, full deployments will be slow. It is expected that the market for these packages will develop and grow in much the same way as anti-lock brakes and air bags came to be a standard feature on most vehicles. Little regional variance is the rate of deployment is expected. Some, such as vehicle safety monitoring and longitudinal safety, may be available in the 5 year time frame.

Significant technical development is needed before deployment of services that are both vehicle- and infrastructure-based. such as intersection safety or automated highway systems. There are also potential liability issues related to any infrastructure control of vehicles.

Table B.4-1 AVSS Deployment Profile

Advanced Vehicle	**Deployment Scenarios**								
Safety Systems	5-year			10-year			20-year		
	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural
Vehicle Safety Monitoring									
Driver Safety Monitoring									
Longitudinal Safety Warning									
Lateral Safety Warning									
Intersection Safety Warning									
Pre-Crash Restraint Deployment									
Driver Visibility Improvement									
Advanced Longitudinal Control									
Advanced Lateral Control									
Intersection Collision Avoidance									
Automated Highway System									
Legend		:Initial Deployment			:Threshold Deployment			:Full Deployment	

Table B.4-2 Influences on AVSS Deployments

Market Package	Deployment Depends on	Timing Considerations	Incentives to Deployment
Vehicle Safety Monitoring	• In-vehicle Technology	• Currently near-term research projects	Reduced accidents
Driver Safety Monitoring	• Driver Condition Sensing Technology • Driver approval	• Significant technical and social issues	Stops impaired drivers from driving
Longitudinal Safety Warning	• Overcoming problems with interference	• Current radar system on Greyhound busses work	Reduced accidents
Lateral Safety Warning	• Sensing technology	• Acoustical warnings of movement out of lane already widely used	Reduced accidents
Intersection Safety Warning	• Technology for estimating likelihood of accident and communicating information to the vehicle • Limiting liability of road operator	• Will potential benefits be great enough to motivate the necessary R&D	Reduced accidents
Pre-crash Restraint Deployment	• Technology for sensing imminent crash without giving false alarms	• Will potential benefits be great enough to motivate the necessary R&D	Less serious injuries in the event of a crash
Driver Visibility Improvement	• Visioning system s superior to the human eye under relatively common conditions	• May be developed as a by-product of visual surveillance systems	Reduced accidents. Reduced driver stress
Advanced Longitudinal Control	• Overcoming problems with interference	• Preceded by longitudinal safety warning	Reduced accidents Increased highway capacity Reduced driver attention required
Advanced Lateral Control	• Sensing technology	• Preceded by lateral safety warning	Reduced accidents Increased highway capacity Reduced driver attention required
Intersection Collision Avoidance	• Development of intersection collision warning	• Preceded by intersection collision warning	Reduced accidents
Automated Highway System	• Development of system for access and egress • Limiting liability of highway operator • Control algorithm and technology	• Long range	Reduced accidents Increased highway capacity Reduced driver attention required

B.5. Commercial Vehicle Operations (CVO)

There are two types of CVO services: one provides electronic support for various regulatory requirements, and the other increases the efficiency of commercial vehicle operations. Public agencies will likely implement the first and private firms the latter. Most freight firms already have systems for dispatching and tracking vehicles and shipments and for maintaining the fleet. Systems that exploit modern electronics and communications technologies for these purposes are being aggressively marketed, and a high level of implementation is expected. Tests of services to facilitate regulatory functions are underway, and those that prove to be cost-effective are likely to be widely adopted.

Table B.5-1 CVO Deployment Profile

Commercial Vehicle Operations	**Deployment Scenarios**								
	5-year			10-year			20-year		
	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural
Fleet Administration									
Freight Administration									
Electronic Clearance									
CV Administrative Processes									
International Border Electronic Clearance									
Weigh-In-Motion									
Roadside CVO Safety									
On-Board CVO Safety									
CVO Fleet Maintenance									
HAZMAT Management									
Legend		:Initial Deployment			:Threshold Deployment			:Full Deployment	

Table B.5-2 Influences on Near Term CVO Deployment

Market Package	Deployment Depends on:	Timing Considerations	Incentives to Deployment
Fleet Administration	• Vehicle location system	• Already in use	Overall fleet efficiency
Freight Administration	• Intermodal coordination • Common cargo tag	• Need cargo tag standard	Optimum cargo routing Customer planning
Electronic Clearance	• Enrollment standard • VRC standard • Tag information standard	• CVISN • VRC depends on spectrum allocation decisions	Time savings for truckers Cost savings for regulators
CV Adminstistrative Processes	• Electronic clearance	• Likely to accompany electronic clearance	Cost savings
International Border Clearance	• International Credentials Agreements are needed • Customs agreements	• Currently working on simple clearance • More work needed on customs	Time savings for truckers Cost savings for regulators
Weigh -in-Motion	• Technology	• Current devices are expensive	Cost savings for truckers and regulators Better enforcement in remote areas
Roadside CVO safety	• VRC standard • Sensors for monitoring safety	• VRC depends on spectrum allocation decisions • Sensors for monitoring safety not yet fully developed	Increased safety
On-Board CVO Safety	• Advanced Sensors	• Current research topic	Continual monitoring of safety of vehicle
CVO Fleet Maintenance		• Already in use	Increased reliability and reduced costs
HAZMAT Management	• Procedures and wide area communication in vehicle	• Clearance package should facilitate procedures • In-vehicle equipment could piggy-back on AVLS capability	More rapid and safer cleanup of hazardous spills

B.6 Emergency Management (EM)

The Emergency Management Services package includes two services provided by public agencies, Emergency Response and Emergency Routing, and one service purchased by vehicle operators, Mayday Support. Emergency response systems are already being tested in Southern California. If they prove effective, they are likely to be highly utilized in congested areas. Emergency routing may have less application because of limited route options and traffic control in many suburban areas. Mayday services will be particularly useful for vehicles that travel on little-used roads where telephones are not located nearby and where there are few other travelers to offer help and notify the road operator that there is a problem.

Table B.6-1 EM Deployment Profile

Emergency	**Deployment Scenarios**								
Management	5-year			10-year			20-year		
	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural
Emergency Response									
Emergency Routing									
Mayday Support									
Legend		:Initial Deployment			:Threshold Deployment			:Full Deployment	

Table B.6-2 Influences on Near Term Emergency Management Services Deployment

Market Package	Deployment Depends on	Timing Considerations	Incentives to Deployment
Emergency Response	• Inter-agency agreements and standards • Better algorithms to support response decisions	• Agencies have difficulty sharing control due to liability issues	Reduced delay Quicker aid to accident victims
Emergency Routing	• Algorithms • Route planning agencies with reliable traffic data	• Traffic data and coordination depend on implementation of other market packages	Reduced delay Easier access for emergency vehicles
Mayday Support	• Current regulations prevent Automate mayday to 911	• Current private organizations provide interface service which will eventually convince public agencies of reliability of equipment	Faster attention to medical emergencies and hazards to vehicles and people

B.7 ITS Planning

Data from road surveillance and subsystem operations can provide valuable information for planning not only ITS deployment but all types of transportation improvements and policies. Relatively little attention has been given to how such data might be used to model the effects of changes in the transportation system or in transportation demand. Because the extent and nature of the information varies significantly from that previously available, there are opportunities for using models and analytical methods that could not be supported by previously available information.

Table B.7-1 ITS Planning Deployment Profile

	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural	Urban	Inter-Urban	Rural
ITS Planning									
Legend		:Initial Deployment			:Threshold Deployment			:Full Deployment	

Table B.7-2 Influences on Near Term ITS Planning Deployment

Market Package	Deployment Depends on	Timing Considerations	Incentives to Deployment
ITS Planning	• Development of models to utilize more extensive information	• Need for better planning methods is recognized	Better estimation of the costs and effects of transportation improvements

Appendix C : Case Studies

To gain insights into the ingredients of a successful implementation strategy, a series of case studies of actual ITS implementations was undertaken. These concentrated on the more mature and widely implemented ITS services: network surveillance, centralized signal control, freeway management, incident management, and traveler information. These represent all but two elements of the ITI, transit management and electronic payment. While the case studies do not represent a random sample of implementations and do not cover all geographic areas or ITI services, they provide a consistent picture of the requirements for successful implementation that is relevant to all ITS services provided by government agencies. These requirements are displayed in Figure C-1 below.

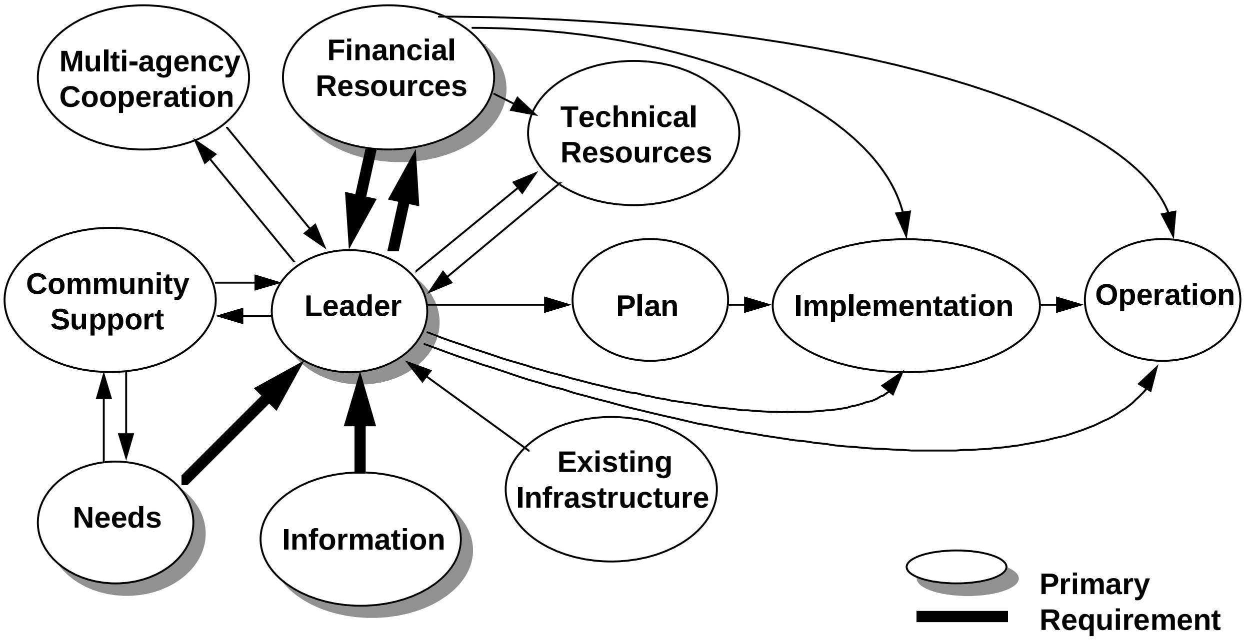


Figure C-1 Requirements for Successful ITS Implementation and Operation

C.1 Requirements for Successful ITS Implementation

The first requirement is a *need*--ITS must meet a perceived need, such as to reduce delay. Given a need, there must be someone or some group to *lead* the implementation. Without such leadership, implementation does not occur. The leader must have *information* necessary to procure a system that will meet the regions needs and must seek out *financial resources*. Given these basic ingredients, community support, multi-agency cooperation, technical resources, and the existing infrastructure can be brought together into an ITS plan and ultimate implementation and operation.

C.1.1 Need

One of the earliest and most extensive implementations of advanced traffic management systems occurred in the city of Los Angeles. This was a clear case of need. With 30% of California's population, 27% of its vehicle-miles, and only 13% of its miles of road, Los Angeles has high levels of congestion both on its freeways and city streets. The city began coordinating traffic signals before 1960 and there have been many generations of systems. In 1980, city staff began planning to centrally control signal systems at three sites: the airport, downtown, and the coliseum. Because of the 1984 Olympics in Los Angeles, the coliseum system was implemented first. ATSAC (Advanced Traffic Surveillance and Control) currently provides centralized control, performance monitoring, and incident detection for about half of the city's 4200 signals; it is expected that all signals will be in the system by the early 2000s. The current system, developed in-house and implemented in 1993, provides second by second control depending on time of day. It observes demand, redefines critical intersections, and plots traffic volumes. The system includes surveillance via loop detectors and closed circuit television (CCTV), signal trunkline communication via fiber optics, signal optimization software, and real-time remote control of signals. Information is provided to travelers via cable TV, the Internet, and a dial-in telephone system. The signal optimization was initially based on the FHWA's UTCS signal control software, but has since been modified to meet the city's needs. The city is working on an expert system to detect incidents and assist in response.

Early evaluations of the ATSAC system found substantial reductions in signal delay. Since the system was implemented, coliseum traffic clears within an hour after a big concert, where previously it took over two hours. The system also detects signal malfunction, which previously had caused unnecessary delay at 24% of the signals. After the Northridge earthquake, the system allowed prompt changes to signal phasing to handle traffic diverted from damaged freeways as well as a means of observing fires and other non-traffic conditions.

Orange County, directly south of Los Angeles County also has very high vehicle delay and a need for improved signal control. In 1988, its largest city, Anaheim, which is home to Disneyland, a convention center, a stadium, and an indoor arena, began installing a centralized signal control system, similar to that in Los Angeles. This system also employs a control system based on the UCTS software. It includes loop detectors, CCTV, changeable message signs, cable TV information, highway advisory radio, a computer bulletin board on the Internet, and two remote kiosks. The system has reduced both event-generated and recurrent congestion, the former by an estimated 30%.

Caltrans and other Orange County cities have also developed traffic management centers. In Santa Ana and Irvine, traffic is monitored via loop detectors and CCTV. Fiber optics provide much of the communications capability. Information is disseminated via highway advisory radio, changeable message signs, and the Internet. These systems are only recently implemented and in the process of implementation, so their effectiveness can not yet be assessed.

Another case of clear need is in San Jose, the largest city in the San Francisco Bay Area, which built a downtown arena and convention center. Concerned about the impact of these facilities on traffic, the city developed a system to manage its traffic signals. The system, begun in 1991, now includes a surveillance network, remote control of signals, highway advisory radio, and changeable message signs.

In the congested suburban area surrounding Washington DC, Montgomery County, Maryland also has seen a need for ATMS. Its system includes real-time control of 600 signals, and ultimately 1500 signals, automated incident detection and management, and information gathering to support transportation planning. It utilizes a 200 camera video surveillance system, aerial surveillance, a fiber optic communication system, and a geographical information system. Information is provided to the public via travel advisory radio, automated variable message signs, and cable TV.

Six cities in the Dallas area have seen a need for ATMS. Dallas developed the first system, and as in the Los Angeles area, suburban cities followed. These cities have centralized traffic control and various means of disseminating information.

But not every congested city or suburb perceives a need for ATMS. Not far from San Jose, is Menlo Park, a small, affluent suburban city that does not want to encourage through traffic on its roads and streets. Therefore there is not strong public support for signal management to reduce delay on these roads and streets. In contrast to San Jose, where the goal of traffic management is service, in Menlo Park, the goal of traffic management appears to be to maintain adequate signalization at minimum cost. The same appears to be true of some of the more affluent Dallas suburbs.

Even in San Francisco, where there is a clear need for traffic management, there is not a perceived need for additional traffic surveillance or real-time signal control. The city has 1020 signals in 32 separate signal systems, but because it is geographically compact and traffic is fairly predictable, installation of a system such as in San Jose was not found to be cost effective. Surveillance and incident reporting is provided by the city’s 300 parking control officers, who are on the street dealing with parking violations. ITS services that are needed in San Francisco, tend to be related to emergency vehicle management, transit, and parking.

Outside of large metropolitan areas there is little need for traffic management. Nevada County, a rural county in Northern California, does not have traffic problems. In the small cities in the county the signals are too far apart to benefit from coordination. Congestion occurs only on I-80 only when there is heavy holiday resort traffic or heavy snowfall. During heavy snowfall, surveillance is provided by a large force of snowplow operators and the highway patrol. Caltrans provides changeable message signs and highway advisory radio regarding highway conditions.

C.1.2 Leadership

In most of the cases studied, the implementation was proposed and lead by professional staff who were interested in exploring new ways to reduce congestion. In Los Angeles it was led by people at the head of the transportation agency and a core group of engineers who appreciated the importance of signal control and enjoyed the challenge of utilizing computers systems for this purpose. At the Orange County Transportation Authority, staff became interested in ITS and developed a master plan. At the Caltrans Orange County District, traffic management staff initiated the traffic management center development. In Santa Ana and Irvine implementation was also led by staff. Anaheim was different. Implementation was motivated by a citizen survey that showed traffic to be the number one problem and a subsequent study that determined that a real-time traffic study was needed. The study was conducted by a consultant and implementation was later taken over by city staff. In San Jose, the city council, concerned about the traffic impacts of the downtown arena and convention center, directed the city's traffic operations department to look into establishing a new, high-tech system to manage its traffic signals, and at this point, staff took the lead in researching and proposing options for the system. In Montgomery County and Dallas, active traffic staffs also took the lead.

C.1.3 Information

Information used by the implementors came from a variety of sources. Los Angeles staff benefited from the federally-developed UCTS software for signal control. They were assisted by JHK, a consulting firm, in adapting the software to the City's system. Since then, the city has been developing its own staff expertise, working directly with equipment suppliers. Later implementors were able to learn from Los Angeles' experience. The Anaheim system is similar to the Los Angeles system in many ways--being UCTS based and developed by the same consulting firm. Irvine, too, followed Los Angeles' lead. Santa Ana, in turn, was influenced by the Anaheim system and used the same consultant. San Jose visited the Los Angeles and Anaheim systems and used the same consultant.

Information on ITS was also available from reports, studies and meetings. Perhaps the reason why so much ATMS is staff led, is that staff have information about ITS. They know people in sites where ATMS has been implemented, they hear about reports and studies, they go to meetings with other traffic professionals.

C.1.4 Funding, Community Support, Multi-agency Cooperation, and Technical Resources

The case studies demonstrated that where there was a will--that is, perceived need, leadership, and information-- there was a way--funding, community support, multi-agency cooperation, and technical resources. The earliest implementors had a need that generated the funding and community support. Later implementors were motivated in part by the availability of funds. The availability of outside funds dedicated to congestion/ transportation management eliminated opposition on the grounds that the funds should be used for something else.

Although the funding sources varied, the first implementors were more likely than other implementors to use local funds. In Dallas, earlier traffic operations investments were bond-funded as part of larger transportation improvement packages. Now such funding is less available and there is a need for outside funding for ITS. San Jose was prepared to fund its system entirely from local funds, but ISTEA provided CMAQ (Congestion Management and Air Quality) funds that were used to accelerate development of the system. Los Angeles has typically used federal funds for repair, replacement, and development of it traffic management systems and has been successful in acquiring the needed funds. Anaheim was successful in lobbying multiple funding sources to provide the funds for its system.

Multi-agency cooperation has costs, and expending resources on cooperation does not make sense unless there are clear benefits to be gained. The agencies studied had found creative ways to work together to improve the traffic situation in both jurisdictions, but the goal was serving their own constituency better, not cooperation for the sake of a regional constituency. It appears that there will be more mutually beneficial opportunities for neighboring jurisdictions to cooperate as the traffic management systems become better developed.

Technical problems often hamper implementation. But in dealing with them the state of the art is advanced, as it was in Los Angeles when the FHWA signal control software was implemented. As technology advances, overall system costs should drop, and ITS should become more attractive to cities that do not now consider it cost-effective, such as San Francisco.

C.2 Architectural Implications

The implementations studied did not have the benefit of an established national architecture or standards. Nonetheless, agencies in Los Angeles and Orange County attained a fair degree of coordination, largely due to the use of FHWA UCTS software for centralized signal control, emulation of the older, larger systems (Los Angeles and Anaheim) and use of the same consultant, JHK, to tailor the software to the cities' needs and some agencies achieved interties with Caltrans, which allowed them to share information. Because each agency's existing infrastructure was unique, the customization of the UCTS software was unique, and this did not result in the open, non-proprietary systems that some agencies would have preferred. Los Angeles would like standards for cross-agency operations. It and others noted the potential for agencies in the same region to help each other, perhaps working with the FHWA, and thus eliminate the need for outside expertise from consultants.

The lack of a national architecture did not prevent these implementations. Conversely, the presence of a national architecture will not produce implementations where the factors discussed above are not present. The benefit of the architecture will lie in facilitating beneficial implementation and reducing its cost.

C.3 Implications for the Implementation Strategy

What conclusions can be drawn regarding an implementation strategy? First, there is no point in promoting ITS in situations where it does not meet a perceived need--promotion should be directed to areas in which the need for ITS services is greatest. Second, the leaders in ITS implementation are professional staff people. This may be because ITS services are less visible than a new freeway or transit system and thus attract less public and political attention. This may actually expedite ITS implementation because it is less likely to attract controversy. Providing more information regarding the benefits and costs to transportation professionals in areas in which ITS services are needed may encourage implementation. Third, money does matter. At the very least, it attracts interest in ITS. However, care must be taken that funding does not distort incentives to the point where ITS projects that are less cost-effective than alternatives are undertaken. Finally, standards setting, information sharing, research or other policies that increase ITS performance or lower its cost should be supported.

In summary:

- Target ITS promotion at areas where ITS is most needed.
- Provide needed ITS information and technical support to transportation professionals in these areas.
- Provide funding for ITS in a way that encourages cost-effective implementation and discourages implementation that is not cost-effective.
- Support standards setting, information sharing, research and other policies that reduce the cost or increase the benefits of ITS implementation.