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ITS Architecture Development Program

Phase I

Summary Report

November 1994

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

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ITS AMERICA

The U.S. Department of Transportation

Through the Inter-modal Surface Transportation Efficiency Act of 1991 (ISTEA), Congress gave the U.S. Department of Transportation (U.S. DOT) the responsibility of providing leadership and guidance necessary to promote national ITS compatibility. To achieve this compatibility, U.S. DOT has initiated a program to develop a national ITS architecture.

ITS AMERICA

The Intelligent Transportation Society of America (ITS AMERICA) is a non-profit educational and scientific association incorporated in August 1990. ITS AMERICA's mission is to accelerate the deployment of ITS in the United States and is chartered as a utilized Federal Advisory Committee to the U.S. Department of Transportation. In 1992, ITS AMERICA identified the development of a national ITS architecture as the program's top research and development priority.

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FOREWORD

A major national initiative is underway to apply proven information, communications and control technologies to surface transportation to improve its efficiency and reduce its negative impacts. Collectively, these applications are known as Intelligent Transportation Systems---or ITS-and are expected to create a $200 billion industry over the next 20 years.

ITS will be applied to all types of vehicles (trucks, buses and cars), to information devices (computers, kiosks, and hand-held devices), and to all parts of the surface transportation system (freeways, urban arterials, rural roads, transit stations, ports, and intermodal terminal connections). Deploying ITS can improve safety, reduce congestion and improve mobility, reduce environmental impact and increase energy efficiency, improve economic productivity, and create a domestic ITS industry.

The U.S. Department of Transportation (U.S. DOT) and the Intelligent Transportation Society of America (ITS AMERICA) are working with many organizations at the national and international level to make ITS a reality.

However, decisions as to the nature and extent of ITS deployment will be made primarily by state, regional and local agencies, transit and commercial fleet operators, consumers, and public interest groups-not U.S. DOT and ITS AMERICA. The ultimate course of ITS will depend upon the collective efforts of these “stakeholders.”

Our transportation system is national in scope, enabling people and goods to move across jurisdictional boundaries with ease. To continue this free movement, Congress has directed U.S. DOT to promote the nationwide compatibility of ITS. To achieve this compatibility, U.S. DOT is in the early stages of a program to develop a common ITS framework-a system architecture. Four alternative architectures are being studied as part of the ITS Architecture Development Program, with the goal of establishing a national ITS architecture by mid-1996.

To be effective, the ITS architecture must meet and balance the needs of many different stakeholders or run the risk of losing the opportunity to deploy ITS in a coherent, integrated manner. The architecture development program has been designed to foster active stakeholder involvement to deliver an architecture that is acceptable to stakeholders, advances their interests and addresses their concerns.

This document provides the latest information on the ITS Architecture Development Program, highlighting the four architectures being developed. Readers are welcome to submit feedback, which will help refine the architectures and identify issues for future consideration. FHWA has announced an open docket, No.94-26, for comments. Comments received up to November 21,1994 may be used as part of the Phase II evaluation process for selecting which team(s) continue into Phase II. Comments received after November 21,1994 may be used to develop Phase II stakeholder focus group discussions.

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BACKGROUND

Surface transportation in the United States is at a crossroads. The mobility we prize so highly is threatened. Many of the nation's roads are badly clogged. Congestion continues to increase, and the conventional approach of the past-building more roads-will not work in many areas of the country for both financial and environmental reasons.

Safety continues to be a prime concern. In 1993, 40,000 people died in traffic accidents and more than 5 million were injured. Public transportation systems, chronically short of funds, are seen by many as an unattractive alternative to driving.

Congestion also takes its toll in lost productivity costing the nation billions of dollars annually. Traffic accidents-many caused by congestion itself-drain away billions more each year. Dollars alone don't account for the loss of life or the consequences of long-term injury. There are also other costs. For example, inefficient movement of vehicles reduces productivity, wastes energy, and increases emissions; trucks, buses, and automobiles idled in traffic waste billions of gallons of fuel and needlessly emit tons of pollutants each year.

Recognition of these problems led to the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The purpose of ISTEA is clearly annunciated in its statement of policy: ***"...to develop a National Inter-modal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner:"***

Goals for ITS in the U.S.

- Improved safety
- Reduced congestion
- Increased and higher mobility
- Reduced environmental impact
- Improved energy efficiency
- Improved economic productivity
- A viable U.S. ITS industry

There is no single answer to the complex transportation problems that confront us. But a group of applications known as Intelligent Transportation Systems (ITS) can help tremendously in meeting the goals of ISTEA. Indeed, Congress recognized this in the Act by authorizing a $660 million program over the next six years. ITS is composed of a number of technologies, including information processing, communications, control, and electronics. Intelligently joining these technologies to our transportation system can save lives, time, and money and improve our quality of life.

ITS can improve safety, reduce congestion, enhance mobility, minimize environmental impact, save energy, and promote economic productivity in our transportation system. It will multiply the effectiveness of future spending on highway construction and maintenance, increase the attractiveness of public transportation, and facilitate efficient intermodal freight movement. ITS will be as basic a transportation raw material as concrete, asphalt, or steel rail.

ITS is not a distant vision. Already, real systems, products, and services are being tested throughout the United States. Some first-generation systems are, in fact, on the market. More than 40 real-world operational tests are now under way or are planned as federal/state/private ventures to evaluate more advanced ITS concepts and equipment.

Over the next 20 years, a national ITS program could have a greater societal impact than even the Interstate Highway System. As with the Interstate, effects are difficult to predict at the outset of the program. Still, it is clear that ITS can yield substantial benefits widely distributed among our society. There are benefits, for instance, for rural drivers as well as those in congested metropolitan areas; for older as well as younger drivers; and for the current riders of public transportation systems as well as those who will be attracted to public transportation by the enhancements that ITS helps make possible.

Because of the anticipated scale of the economic, legal, and social effects of ITS, it is important that there be penetrating, systematic evaluation of ITS, particularly in its early stages. To achieve this systematic evaluation at the national level, a program planning process has been established by which all interested parties in ITS can work together to implement ITS. An early outcome of the planning process was the identification of a number of capabilities-“user services”-that, if deployed, will collectively meet the goals of ITS.

Currently, there are 29 user services which fall into the following seven general areas. These services and service areas may change over time as more information is gained from tests and more groups get involved in ITS. Some services have already been regrouped into a Travel Demand Management bundle and an Emissions Testing and Mitigation service was added in July 1994.

Travel and Traffic Management services provide an array of information services to help travelers plan trips and avoid delays. This category of services also provides improved surveillance and traffic control procedures and mechanisms to improve transportation system efficiency.

Travel Demand Management services provide information and incentives to manage transportation demand and encourage the use of high-occupancy vehicles.

Public Transportation Management services improve the efficiency, safety, and effectiveness of public transportation systems for providers and customers alike. This category of services will make public transportation more attractive to potential customers.

Electronic Payment service automates financial transactions for all modes of surface transportation. This will help reduce delays in fee collection and provide accurate data for systems management.

Commercial Vehicle Operations services streamline administrative procedures, improve safety, and help efficiently manage commercial fleets.

Emergency Management services improve emergency notification and response times and enhance resource allocation.

Advanced Vehicle Control and Safety Systems services provide various forms of collision avoidance and safety precautions. Automated vehicles remain a longer-term objective.

ITS User Services

Travel and Transportation Management

> En-Route Driver Information
> Route Guidance
> Traveler Services Information
> Traffic Control
> Incident Management
> Emissions Testing and Mitigation*

Travel Demand Management

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

Public Transportation Operations

> Public Transportation Management
> En-Route Transit Information
> Personalized Public Transit
> Public Travel Security

Electronic Payment

- Electronic Payment Services

Commercial Vehicle Operations

- Commercial Vehicle Electronic Clearance
- Automated Roadside Safety Inspection
- On-Board Safety Monitoring
- Commercial Vehicle Administrative Processes
- Hazardous Materials Incident Response
- Commercial Fleet Management

Emergency Management

- Emergency Notification and Personal Security
- Emergency Vehicle Management

Advanced Vehicle Control and Safety Systems

- Longitudinal Collision Avoidance
- Lateral Collision Avoidance
- Intersection Collision Avoidance
- Vision Enhancement for Crash Avoidance
- Safety Readiness
- Pre-Crash Restraint Deployment
- Automated Highway Systems

* Added July 1994
* * Renamed from Travel Demand Managemen

ITS development is moving rapidly and products are already coming to market in many of these areas. Requirements definition for some areas is evolving in parallel with deployment in others. The goal, nonetheless, is a well-integrated system in which the services are all linked practically and cost-effectively to provide greater capabilities than could be achieved separately.

This document focuses on a major initiative in the ITS program aimed at achieving the goal of an integrated system for ITS applications-the ITS Architecture Development Program. This document serves as a status report on the architecture development program. Readers are welcome to submit feedback, which will help refine the architectures and identify issues for future consideration.

THE ITS ARCHITECTURE DEVELOPMENT PROGRAM

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) gives U.S. DOT the responsibility of providing the leadership and guidance necessary to promote national ITS compatibility over the long term. That compatibility relies upon establishing a unifying national ITS architecture.

A thoughtfully designed architecture will ensure that the deployment of ITS user services occurs within the most sensible system framework. It will also ensure that a nationally compatible system linking all modes of transportation emerges, instead of local or regional pockets of ITS that will not accommodate intercity travel or cross-country goods movements.

The establishment of a national ITS architecture will not only ensure national compatibility but also be beneficial to individual stakeholders. An architecture will allow stakeholders to adopt the elements of ITS in the manner and timeframe of their choosing and will serve as the foundation for standards that can reduce duplication of effort by the stakeholders, speed the introduction of ITS products and services, and reduce the risk for the private sector developing these products and services, as well as the public sector who may be deploying the various systems.

Schedule

U.S. DOT has initiated the National ITS Architecture Development Program with the aim of developing an architecture by mid- 1996. In September 1993, U.S. DOT selected teams led by Hughes Aircraft, Loral, Rockwell International, and Westinghouse Electric to each develop an alternative ITS architecture. Each architecture is based on a twenty-year planning horizon (1992-2012) and addresses the current set of user services. The program is proceeding in two phases. Phase I of the architecture development program is nearly complete. As of October 1994, each

System Architecture and ITS

What is a System Architecture

- ✔ System engineering methodologies have been created to develop and implement large multifaceted systems like ITS. These methodologies are commonly used in defense and aerospace programs and in technology-based commercial systems, such as computers and communications. The initiation of major new systems is the development of a system architecture.

- ✔ A system architecture is the framework that describes how system components interact and work together to achieve total system goals. It describes the system operation, what each component of the system does and what information is exchanged among the components.

- ✔ A system architecture is different from a system design. Within the framework of an architecture, many different designs can be implemented. Home stereo systems provide a good example of the importance of establishing an architecture. Consumers, or users, determine what capabilities they want in a stereo system (e.g., compact disk, tape player or turntable) based on cost and performance. Since the home stereo industry has an established architecture, product suppliers offer components that consumers know will work together.

ITS Architecture

- ✔ The development of an architecture is a systematic process. It involves understanding goals, requirements, different operational concepts, and enabling technologies to provide important system capabilities. The User Services can be thought of as the requirements of an ITS architecture.

- ✔ A well-defined ITS architecture will accommodate different levels of implementation, different systems designs and flexibility to allow system evolution over time. This allows different goals to be supported across many regions. For example, different user services will be important to rural and urban areas.

- ✔ In addition, the well-developed ITS architecture will:

  - Foster evolutionary development of ITS that readily accommodates new products as needs and goals change and technology advances;
  - Reduce the cost of individual components by clearly defining their functions, encouraging competition by the sector; and
  - Identify necessary interfaces between components, an essential step toward defining common interface standards and protocols.

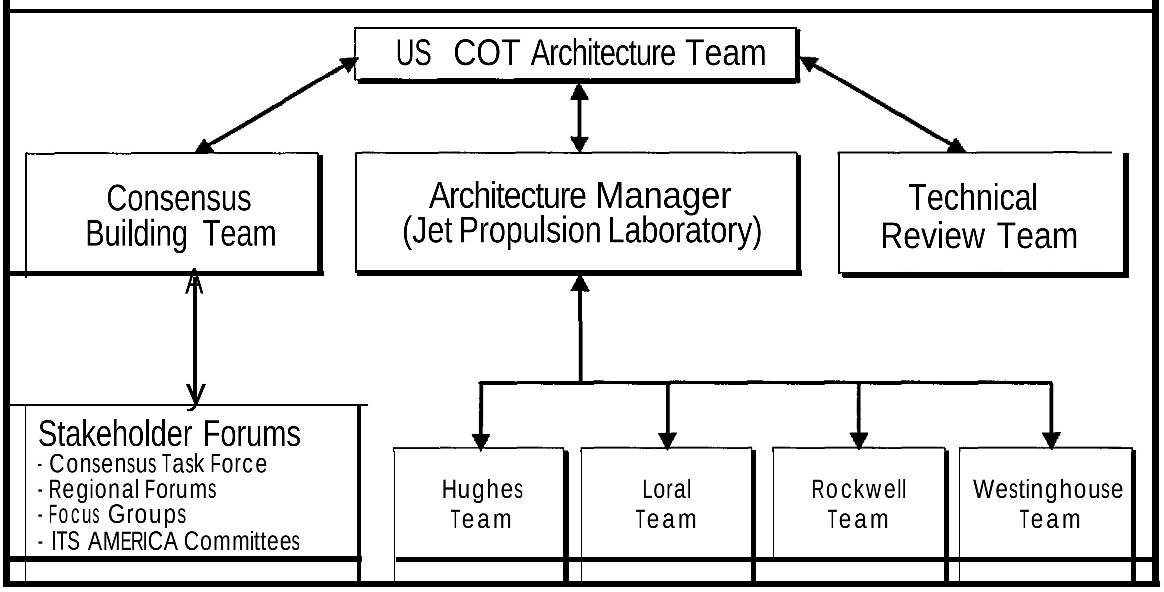
team has developed an initial architecture concept and performed a preliminary evaluation of that concept. The rest of Phase I, roughly through January 1995, is a review and evaluation period. The team(s) with the most promising approach(es) will continue into Phase II, which will run from February 1995 to July 1996.

In Phase II, the remaining team(s) will be working in an open, collaborative environment. The goal of Phase II is to develop a single national consensus architecture. Early in the phase, the remaining team(s) will have the opportunity to integrate elements of the other architecture approaches as they feel is appropriate. Meetings of experts from the remaining teams will occur early in Phase II to identify areas of commonality. Throughout Phase II, there will be numerous meetings of teams and stakeholders to address unresolved issues (i.e., holes in the architecture). It is likely that most of the elements of a national architecture will be in place by late 1995/early 1996. The end of Phase II will be used to fully document the national architecture. In addition to developing the architectures, the teams will be working to develop interface standards requirements and implementation strategies for the architecture.

Organizational Structure

Management of the architecture development program is vested in the U.S. DOT Architecture Team, comprised of representatives from U.S. DOT's Federal Highway Administration, Federal Transit Administration, and National Highway Traffic Safety Administration, as well as the MITRE Corporation. The Jet Propulsion Laboratory serves as the Architecture Manager, providing day-to-day management oversight of the teams. A team of technical experts-the Technical Review Team-reviews the technical soundness of the architecture alternatives by reviewing documentation submitted by the teams at certain program milestones. A consensus building team, staffed jointly by U.S. DOT and ITS AMERICA, transmits information to and receives feedback from interests outside the technical development program.

Organizational Structure



ITS Architecture Consensus Task Force

American Association of Motor Vehicle Administrators
American Association of State Highway and Transportation Officials
American Association of Port Authorities
American Association of Retired Persons
American Automobile Association
American Automobile Manufacturers Association
American Bus Association
American Consulting Engineers Council
American Electronics Association
American Portland Cement Alliance
American Public Transit Association
American Public Works Association
American Road and Transportation Builders Association
American Trucking Associations
Association of American Railroads
Council of Standards Organization
Council of University Transportation Centers
Electronic Industries Association
Environmental Defense Fund
Human Factors and Ergonomics Society
Institute for Transportation Engineers
International Bridge, Tunnel and Turnpike Association
International Taxicab and Livery Association
IVHS Canada
National Association of Counties
National Association of Governors' Highway Safety Representatives
National Association of Regional Councils
National Conference of State Legislatures
National Emergency Numbers Association
National Governors' Association
National Industrial Transportation League
National League of Cities
National Private Truck Council
National Safety Council
Public Technology, Incorporated
State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials
Surface Transportation Policy Project
Telecommunications Industry Association
TRANSCOM
United Bus Owners of America
United States Chamber of Commerce

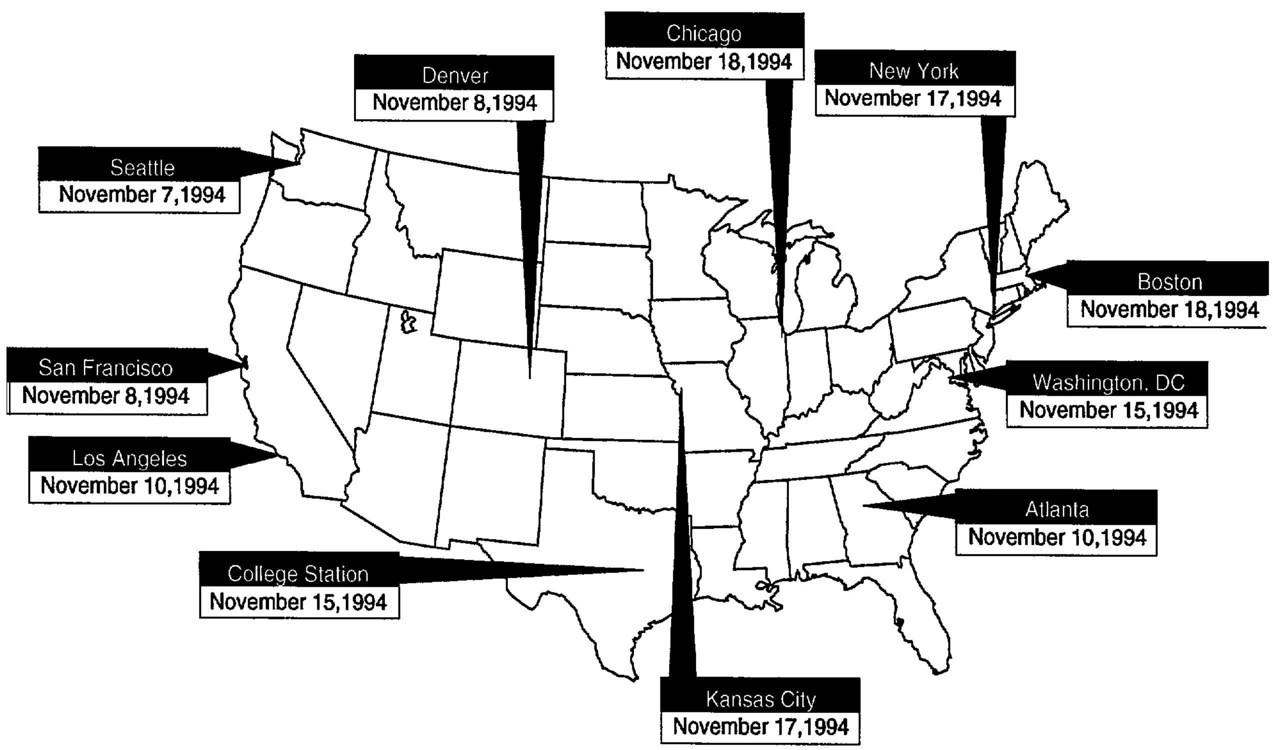
Consensus Building

It is vital that the architecture be designed in a systematic fashion so that all issues are addressed openly and directly, rather than having the architecture evolve in an ad hoc fashion. Those who will use, design, build, operate, maintain, and be impacted by these systems must jointly decide upon a common system architecture. These stakeholders have helped design a consensus building process to gain cooperation among many different stakeholders in achieving the goal of a nationally compatible intelligent transportation system. Since critical policy issues are being addressed by the architecture alternatives, the consensus building process allows-and ensures-that stakeholders are aware of these policy issues and are able to provide meaningful feedback and input as it relates to these issues.

Consensus building activities will focus around major program milestones. At these points, or "review cycles," the latest information on the developing alternatives will be disseminated to stakeholders, along with mechanisms to provide feedback. Four methods are being used to interact with ITS stakeholders:

- ITS **Architecture** Consensus **Task Force.** Comprised of approximately 40 ITS stakeholders, primarily associations/societies and interest groups. Task Force members transmit information to and present feedback from their constituents' perspectives. Representation on the Task Force continues to evolve as the program progresses.

ITS Architecture Regional Forums



- **Regional Architecture Forums.** After each major review, public meetings will be held throughout the country to present the current status of the architecture alternatives and allow local feedback.

- **ITS AMERICA.** The technical committees, task forces and state chapters of ITS AMERICA will be provided with information and will generate feedback on the architecture alternatives.

- **Focus Groups.** As appropriate, focus groups will be conducted to provide a better understanding of key issues and the views of key stakeholders. Focus groups will be utilized extensively in Phase II.

Status

The first program milestone was the Phase I Interim Program Review in March 1994. The second milestone has arrived. Phase I is nearly complete. In early October, each architecture development team delivered documentation summarizing their architecture developed in Phase I. The remainder of Phase I is a review and evaluation period. The architectures will be assessed for technical soundness and desirability to stakeholders. The most promising team(s)/architecture(s) will continue into Phase II, scheduled to begin in February 1995.

Stakeholder Evaluation

Input from stakeholders will play a large role in determining which team(s) proceed into Phase II. To enable stakeholders to review the elements of ITS and the architectures and the related issues that are of interest to them, seven stakeholder categories have been identified. Collectively, these groups attemp to span the spectrum of ITS stakeholders.

The rest of this report is structured so that information is presented from the perspective of each stakeholder. This format allows stakeholders to quickly scan the report for material of interest.

ITS Stakeholder Groups

■ **Consumers**	Commuters, business travelers, leisure travelers, special needs users.
■ **Transportation Infrastructure Providers and Planners**	States, MPOs, counties, cities, toll authorities.
■ **Freight Operations**	Carriers, rail, shippers, regulators, and port authorities.
■ **Public Safety Services**	Police, fire, emergency medical services, towing operators, HAZMAT, emergency managers.
■ **Passenger Operations**	Transit agencies and private fleet operators (e.g., taxis).
■ **Product and Service Providers**	Vehicle manufacturers, communications and information technology products, system integrators and consultants, construction, and businesses serving people on the move.

USER SERVICES

User services define the capabilities that ITS will provide to customers. The ITS community's planning activities currently identify 29 user services in seven categories. While still evolving, these user services collectively define near, mid, and long-term capabilities of ITS. Consequently, each architecture will address all of the following user services.

Travel and Traffic Management

En Route Driver Information. Improves convenience and efficiency with driver advisories and in-vehicle signing.

Traveler Services Information. Provides a reference directory, or "yellow pages" of service information.

Route Guidance. Provides travelers with instructions on how to efficiently each their destinations.

Incident Management. Helps officials quickly identify incidents and implement a formalized set of procedures to minimize their effects on traffic.

Traffic Control. Manages the movement of traffic on streets and highways.

Emissions Testing and Mitigation. Provides area-wide pollution information for monitoring air quality and framing air-quality improvement strategies.

Travel Demand Management

Pre Trip Travel Information. Provides information for selecting transportation modes that best suits travelers' needs.

Ride Matching and Reservation. Serves as a mechanism for increasing the attractiveness of shared-ride transportation.

Demand Management and Operations. Manages access to roadways and bridges, supporting policies and regulations like the 1990 Clean Air Act Amendment.

Public Transportation Management

En Route Transit Information. Provides information to travelers using public transportation while on their trips.

Public Transportation Management. Automates operations, planning, and management functions of public transit systems.

Personalized Public Transit. Flexibly routes transit vehicles, offering more convenient service to customers.

Public Travel Security. Creates a more secure environment for public transportation patrons and operators.

Electronic Payment

Electronic Payment Services. Allows payment for transportation related transactions without cash.

Commercial Vehicle Operations

Commercial Vehicle Electronic Clearance. Facilitates domestic and in-temational border clearance, minimizing stops.

Automated Roadside Safety Inspection. Focuses on improving safety in commercial vehicle operations.

ITS User Services

Travel and Transportation Management

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

Travel Demand Management

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

Public Transportation Operations

- Public Transportation Management
- En-Route Transit Information
- Personalized Public Transit
- Public Travel Security

Electronic Payment

- Electronic Payment Services

Commercial Vehicle Operations

- Commercial Vehicle Electronic Clearance
- Automated Roadside Safety Inspection
- On-Board Safety Monitoring
- Commercial Vehicle Administrative Processes
- Hazardous Materials Incident Response
- Commercial Fleet Management

Emergency Management

- Emergency Notification and Personal Security
- Emergency Vehicle Management

Advanced Vehicle Control and Safety Systems

- **Longitudinal Collision Avoidance**
- Lateral Collision Avoidance
- Intersection Collision Avoidance
- Vision Enhancement for Crash Avoidance
- Safety Readiness
- Pre-Crash Restraint Deployment
- Automated Highway Systems

* Added July 1994
** Renamed from Travel Demand Management

Commercial Vehicle Administrative Processes. Provides electronic purchasing of credentials and automated mileage and fuel reporting.

On-Board Safety Monitoring. Senses the safety status of a commercial vehicle, cargo, and driver.

Commercial Fleet Management. Provides communications between drivers and dispatchers for efficient routing.

Hazardous Material Incident Response. Provides immediate notification of an incident and immediate request for assistance.

Emergency Management

Emergency Vehicle Management. Efficiently tasks available resources and directs them to incidents, reducing response time.

Emergency Notification and Personal Security. Provides immediate notification of an incident and immediate request for assistance.

Advanced Vehicle Control and Safety Systems

Longitudinal Collision Avoidance. Prevents head-on and rear-end collisions with other vehicles and pedestrians.

Lateral Collision Avoidance. Prevents collisions or vehicles leaving their own lane.

Intersection Collision Avoidance. Prevents collisions involving right-of-way violations at intersections.

Vision Enhancement for Crash Avoidance. Improves the driver's ability to see the roadway and obstacles.

Safety Readiness. Provides warnings regarding the condition of the driver, vehicle, and roadway infrastructure.

Pre-Crash Restraint Deployment. Anticipates an imminent collision and activates passenger safety mechanisms prior to collision.

Automated Highway Systems. Fully automates vehicles on instrumented highways, significantly improving today's safety, efficiency, and comfort standards.

STAKEHOLDER PERSPECTIVES

Consumers, transportation infrastructure providers, freight operators, passenger operators, and public safety officials directly benefit from ITS user services. However, everyone benefits from increased mobility, safety, energy efficiency, and environmental quality. While ITS includes stakeholders and capabilities beyond the perspectives listed below, this description provides an insightful view of an otherwise dull list of user services.

Consumers

Travelers of all types; commuters, business travelers, and leisure travelers define the "ITS consumer." Travelers will be able to access a wide range of information from their homes, offices, and other places where trips begin. This information could include the best mode of transportation based on individually selected criteria, efficient routes, and optimal departure times.

For example, a business traveler needing to catch his airline flight logs onto his computer at home and finds that heavy construction around the airport considerably narrows his alternatives. Ultimately, he decides that his best option is driving part of the way and then catching the train to the airport. A commuter, on the other hand, may access real-time traffic conditions via telephone before leaving for work. He selects an alternate route that avoids the vicinity of that same airport altogether.

INDIVIDUAL DRIVERS

Timely updates of traffic conditions, incidents, construction, transit schedules, and alternate routes will help drivers on the road minimize their travel times-timeliness is the key. Advanced information and communication systems will help drivers avoid hearing that awful traffic report on the radio, while already staring at miles of brake lights. ITS will also accommodate the capability to automatically send a ***distress signal*** to authorities in case of an accident, or manually, to identify mechanical breakdowns or security incidents.

A business directory, or "yellow pages," of service information will inform travelers about the location, operating hours, and availability of food, lodging, parking, hospitals, police facilities, and maybe even points of interest. Fully integrating these services could give a tourist, for example, directions to the nearest golf course based on his current location, or directions to the beach with the biggest boardwalk.

Electronic payment schemes will provide a way for commuters, business travelers, and tourists to use toll roads and bridges without having to stop at toll booths. One day people may be able to buy their fast food at a drive through window without needing cash.

ITS will also provide an array of services to improve safety for drivers (and their passengers). Such capabilities will prove especially useful in rural locations where accidents tend to be quite serious. ITS will help enhance a driver's vision under adverse conditions, and even display important signs in the vehicle. The capability to unobtrusively monitor a driver's condition and provide warnings when appropriate, can help drivers avoid falling asleep at the wheel. Monitoring critical vehicle components and roadway conditions could help avoid a serious incident. Lastly, various sensors will help detect impending collisions and deploy safety restraints.

HIGH-OCCUPANCY-VEHICLE RIDERS

A service that links individual drivers with people needing rides allows all parties to take advantage of reserved high-occupancy-vehicle lanes appearing in many major metropolitan areas. A simplified example of ride sharing already exists in the Northern Virginia suburbs of Washington, DC. The ITS service, however, will match rides and riders based on personal preferences, schedules, and destinations.

ITS will provide real-time, accurate transit schedule and fare information to transit patrons en-route, helping to foster efficient transfer decisions and itinerary modifications. Electronic payment methods will also alleviate the need for exact change. On some rainy day in the future, transit patrons won't get soaking wet while waiting for the passenger in front of them to dig into their pockets and sort through their lint, gum wrappers, and loose change before getting on the bus.

Improving the flexibility of service may also help to increase transit ridership. Small publicly or privately operated vehicles could provide on-demand routing, picking up passengers who request service. ITS will also help create a secure environment for transit patrons using surveillance systems and emergency alarms throughout facilities and vehicles.

Transportation Providers

ITS will give transportation providers the means for controlling roadway operation and usage. Transportation providers include state and local departments of transportation, metropolitan planning organizations, and transit agencies. In the future, innovative public/private partnerships may offer the best approach for financing and operating our roadway transportation system. Therefore, these ITS capabilities are also germane to the private sector and policy interest groups.

Transportation providers can improve the movement of people and goods using ITS capabilities for adaptively controlling rights-of-way and traffic signals. ITS capabilities will also help quickly identify and respond to incidents, minimizing their effects on traffic.

ITS will accommodate travel demand management strategies for reducing the number of single occupants in vehicles and maximizing options for high-occupancy-vehicle use. Officials could ultimately apply travel demand management dynamically when congestion or pollution conditions warrant. For example, authorities will have the ability to charge more for access to say, the Bay Bridge connecting Oakland and San Francisco, during peak congestion hours. Overall, transportation infrastructure providers will benefit from better informed travelers within the transportation system.

Freight Operations

Moving freight is the life blood of the national economy. Improvements in fleet management and streamlined regulations are important in the trend toward ***just-in-time*** delivery supplies. ITS will provide real-time traffic information and commercial vehicle location, helping fleets avoid congested areas and improving the efficiency of pickup and delivery operations.

As a government regulated industry, freight operations adhere to strict safety regulations. Automated roadside safety inspections will provide authorities with real-time access to the safety performance record of carriers, vehicles, and drivers. ITS will also allow truckers to receive indications of the safety status of their vehicle and cargo and warnings of their own condition.

The administrative burden on carriers to collect and report mileage and fuel purchases in each state is significant. ITS will use information technologies to accommodate electronic purchasing of credentials and automated mileage and fuel reporting. Electronic safety, weight, and credential checks will also help trucks pass domestic and international borders without delay. Freight operators will also benefit from the same safety services that will be available to consumers.

Emergency Services

ITS will provide special fleet management capabilities to police, fire, and emergency medical units. Authorities will be able to dispatch the units that can most quickly arrive on the scene of an emergency, given their locations and status. Equipment in the vehicle will direct units to their destination, while traffic signals will give priority to their passage.

Authorities will also receive immediate notification of an incident, and an indication if it involves hazardous material cargos. This notification will include details about the material or materials involved. Timely information will help response teams handle a potentially dangerous situation properly.

Passenger Operations

Information technologies will automate public transportation operations, planning, and management functions. For example, information about passenger loading, running times, and mileage accrued could help improve service. Transit drivers will also receive real-time information about traffic and weather conditions.

Transit and private fleet operators will also benefit from the same safety services that will be available to consumers. In addition, transit property will be properly maintained to create a secure environment for patrons. Dispatchers of private fleets, like taxis, will share many of the efficiencies that ITS offers freight and emergency services fleet dispatchers, especially avoiding congestion. Overall, passenger operations stakeholders will benefit from better informedtravelers.

STAKEHOLDER INTERESTS

During the period from April 21 through-May 11, 1994, the consensus building team (U.S. DOT and ITS AMERICA) conducted a series of ten public ITS architecture forums across the country. Primary goals for these meetings included: educating stakeholders on ITS in general and system architecture in particular and listening to stakeholders' concerns, needs, and issues. Despite the generic nature of the architecture concepts, the forums served as a means for the consensus building and architecture development teams to gain a better understanding of the needs, issues, and concerns of potential ITS providers and users.

In the first series of forums, architecture ***implication ureas*** were discussed and reviewed. The implications are a universal view of all the potential issues that any stakeholder might perceive as important when considering an architecture. The ITS AMERICA and U.S. DOT document entitled ***Architecture Development Program Interim Status Report*** published in April 1994, lists a thorough description of ***implications.***

The April/May forums have provided sufficient feedback to determine which implications are of interest to which stakeholder groups. The following stakeholder interests provide a starting point for assessing the architectures.

Implications	
■ **Deployment**	Impact on the rate of ITS deployment
■ **Equity**	Effect on the distribution of costs and benefits
■ **Financing**	Impact on financing deployment, operations, and maintenance
■ **Institutions**	Impact on institutions and organizations
■ **Market**	Effect on the development of an ITS market
■ **Operations & Maintenance**	Impact of operating and maintaining ITS
■ **Policy & Regulation**	Effect on implementing current and future policies and regulations
■ **Privacy**	Effect on the privacy of individuals and organizations
■ **Safety**	Impact on transportation system safety
■ **Standards**	Effect on current and future standardization efforts.

COMMON INTERESTS

Every stakeholder group is interested in an architecture's projected impact on the deployment of the ITS applications of interest to that group. Thus, all stakeholder groups have an interest in the types of services and capabilities an architecture provides, when these services are expected to become available and the approximate benefits and costs, referred to as deployment-oriented specifics.

To reflect its importance with each stakeholder group, each of the following stakeholder sections will contain a deployment-oriented specifics category in the chart summarizing the interests of that stakeholder group. The remaining ***stakeholder interests*** are essentially high priority implication areas of concern to particular stakeholder groups. ***These topics serve as a starting point for stakeholder review and evaluation-they are not exhaustive.***

Consumers

Privacy and User Autonomy. Privacy is a general topic that includes three important features for consumers. Anonymity defines the safeguards in an architecture that prevent unlawful tracking of users. Voluntary participation describes the degree to which an architecture mandates ITS participation and the mechanisms for encouraging participation. User control is a potentially important factor effecting wide acceptance of ITS among consumers. The authority and responsibilities of government entities and other service providers may impact the perception of the control users exercise over their mobility.

Consumers' Interests- SUMMARY

- **Deployment-oriented specifics:**
  - * ITS availability over time and across regions (i.e. urban, interurban, and rural)
  - * Service packages, or groups of complementary capabilities
  - * Approximate costs of services/equipment
  - * Approximate benefits of services
- **Privacy and Autonomy:**
  - * Level of anonymity
  - * Level of voluntary or mandatory participation
  - * Level of users' control over their mobility

Transportation Infrastructure Providers

Partnership. Financial partnerships refer to innovative public/private financing arrangements that an architecture encourages, accommodates, or precludes. These partnerships could play an important role in deployment given scarce public funds and a strong, high-technology defense industry looking for new business ventures. An architecture may, for example, offer a structure conducive to private sector investment and profit. Public/public partnerships may also be important. Institutional partnerships involve cooperative arrangements among different organizations. Architecture alternatives may encourage, accommodate, or preclude such partnerships. For example, an architecture may require coordination among all agencies in a given region that have traffic control responsibilities.

Standards/Compatibility. Compatibility with existing products, services, equipment, and standards is important. Transportation infrastructure providers are also interested in the existing standards that an architecture exploits and the magnitude of new standards that an architecture will identify. Standards are important for system interoperability and fostering product competition, which reduces long-term costs. Standards also impact infrastructure concerns, to the extent that an architecture exploits equipment and systems already procured (a potential cost-saving measure). New infrastructure requirements for an architecture represent the investment necessary for fielding specific capabilities.

Operations and Maintenance. O&M is a broad topic including cost considerations and the role of institutions in operations and maintenance plans and activities. While costs closely relate to particular deployment plans, infrastructure providers want to consider life-cycle cost as a whole. Costs estimates may be qualitative, owing to the complexity and variation in the architecture development teams' assumptions. The reliability of deployed ITS elements within an architecture also concerns transportation infrastructure providers. This factor identifies the extent to which an architecture fosters system reliability (e.g., redundancy of functions and robust operations).

Transportation Infrastructure Provider's Interests - SUMMARY

- **Deployment-oriented specifics:**
  - ITS service availability over time and across regions (i.e. urban, interurban, and rural)
  - Service packages, or groups of complementary capabilities
  - Approximate costs of services/equipment
  - Approximate benefits of services
- **Partnerships:**
  - Public/private financial options
  - Cooperative options among institutions and organizations
- **Standards/Compatibility:**
  - Compatibility with existing products, services, equipment, and standards
  - Identify and facilitate the development of new standards
- **Operations and Maintenance:**
  - Life-cycle costs for operations and maintenance

Freight Operations

Privacy. Privacy topics from a freight operations perspective includes two primary elements. Labor privacy addresses labor's perceptions of lost personal privacy. Carriers are concerned with measures for protecting business-sensitive data transmissions and storage. An architecture may affect both.

Policy & ***Regulation.*** Architectural mechanisms for fostering, precluding, or accommodating additional regulation within the freight industry are important topics. Regulators have an interest in implementing and enforcing safety, tax, and import/export regulations. Carriers are interested in ways of facilitating compliance with such regulations, but are probably less enthusiastic about mechanisms that make implementing additional regulation especially easy.

Standurds/Compatibility. Compatibility with existing products, services, equipment, and standards is paramount. Freight operations stakeholders are interested in the existing standards that an architecture exploits and the magnitude of new standards that an architecture will identify. Standards are important for system interoperability and fostering product competition, which reduces long-term costs.

Freight Operations Interests - SUMMARY

- **Deployment-oriented specifics:**
  - ITS availability over time and across regions (i.e. urban, interurban, and rural)
  - Service packages, or groups of complementary capabilities
  - Approximate costs of services/equipment
  - Approximate benefits of services
- **Privacy:**
  - Level of privacy for labor force (e.g. managerial monitoring)
  - Data Security-protection of business sensitive data
- **Policy & Regulation:**
  - Safety, tax, and import/export options
- **Standards/Compatibility:**
  - Compatibility with existing products, services, equipment, and standards
  - Identify and facilitate the development of new standards

Public Safety Services

standards/Compatibility. Compatibility with existing products, services, equipment, and standards is important. Public Safety Services stakeholders are interested in the existing standards that an architecture exploits and the magnitude of new standards that an architecture will identify. Standards are important for system interoperability and fostering product competition, which reduces long-term costs.

Public Safety Services Interests - SUMMARY

- **Deployment-oriented specifics:**
  * ITS availability over time and across regions (i.e. urban, interurban, and rural)
  * Service packages, or groups of complementary capabilities
  * Approximate costs of services/equipment
  * Approximate benefits of services
- **Standards/Compatibility:**
  * Compatibility with existing products, services, equipment, and standards
  * Identify and facilitate the development of new standards

Partnerships. Institutional partnerships involve cooperative arrangements among different organizations. Architecture alternatives may encourage, accommodate, or preclude such partnerships. For example, an architecture may advocate a single management focal point for all public safety agencies in a given region.

Passenger Operations

Standards/Compatibility. Compatibility with existing products, services, equipment, and standards is important. Passenger operations stakeholders are interested in the existing standards that an architecture exploits and the magnitude of new standards that an architecture will identify. Standards are important for system interoperability and fostering product competition, which reduces long-term costs.

Operations and maintenance. O&M is a broad topic including cost considerations and the role of institutions in operations and maintenance plans and activities. While costs closely relate to particular deployment plans, passenger operations stakeholders want to consider life-cycle costs as a whole. Costs estimates may be qualitative, owing to the complexity and variation in the architecture development teams' assumptions. The reliability of deployed ITS elements within an architecture also concerns passenger operations. This factor identifies the extent to which an architecture fosters system reliability (e.g., redundancy of functions and robust operations).

Passenger Operations Interests - SUMMARY

- **Deployment-oriented specifics:**
  * ITS availability over time and across regions (i.e. urban, interurban, and rural)
  * Service packages, or groups of complementary capabilities
  * Approximate costs of services/equipment
  * Approximate benefits of services
- **Standards/Compatibility:**
  * Compatibility with existing products, services, equipment, and standards
  * Identify and facilitate the development of new standards
- **Operations and Maintenance:**
  * Life-cycle costs for operations and maintenance
  * Roles and procedures of institutions and organizations, including staff skills necessary
  * System reliability

Product and Service Providers

Market. An architectural approach will foster service packages that link directly to expected markets, which in turn, drive investment decisions. An architecture's approach may also require or preclude certain technologies, especially impacting small to mid-sized product providers.

Partnerships. Financial partnerships refer to innovative agreements between public and private organizations that an architecture may accommodate, preclude, or encourage. Costs refer to the investment requirements that product and service providers need to consider, especially significant infrastructure investments.

Institutional partnerships involve cooperative arrangements among different organizations. Architecture alternatives may encourage, accommodate, or preclude such partnerships. For example, an architecture may require coordination among all public and private entities in a given region that relies on private ITS service providers.

Standards/Compatibility. Compatibility with existing products, services, equipment, and standards is important. Existing standards that an architecture exploits and the magnitude of new standards that an architecture will identify interests product and service providers. Standards, in general, foster competition and encourage private sector product development.

In business, uncertainty is equivalent to risk. Therefore, the private sector may prefer an architecture that exploits existing standards to the maximum possible extent. Explicitly identifying new standards requirements, where none currently exist, could also help reduce the risks of an architectural approach from a product development perspective. However, some may view standards as detrimental to innovation.

Product and Service Providers Interests - SUMMARY

- **Deployment-oriented specifics:**
  - ITS availability over time and across regions (i.e. urban, interurban, and rural)
  - Service packages, or groups of complementary capabilities
  - Approximate costs of services
  - Approximate benefits of services
- **Market:**
  - Market size
  - Evolution and growth over time
  - Small and large businesses access to markets
- **Partnerships:**
  - Public/private financial options
  - Cooperative options among institutions and organizations
- **Standards/Compatibility:**
  - Compatibility with existing products, services, equipment, and standards
  - Identify and facilitate the development of new standards

GENERIC ITS ARCHITECTURE PRINCIPALS

This section provides background information for reviewing the architecture alternatives. The content is generic in nature, including clarification of the relationship of system architecture, system design, and policy decisions; definition of fundamental concepts for understanding ITS architectures and descriptions of their relevance to stakeholders.

SYSTEM DECISIONS

ITS deployment requires many decisions that tend to fall into one of three categories: System Architecture, System Design, and Policy.

System architectare decisions define the overall framework for ITS deployment. An architecture assigns functions-the equivalent of roles and responsibilities-to specific ITS components. For example, an architecture determines the types of functions performed in a vehicle, as well as the kind of information that passes between the vehicle and the infrastructure, or the transportation management center. An architecture does not necessarily constrain how to perform these functions, roles, and responsibilities (e.g., the best technologies, equipment, or software).

System design decisions collectively specify how to provide the ITS capabilities that users want. For example, stakeholders may have an interest in route guidance capabilities, which requires position location. A system architecture may assign responsibility for the position location function directly to vehicles and identify the type of information required. One stakeholder may design or buy equipment using GPS satellite-based positioning. Another may rely on sensors within the vehicle. Either design provides the position location information required within the architecture framework. Other designs could suffice as well.

Policy decisions, coming from government agencies, may exploit ITS capabilities to help meet their objectives. For example, a local or regional agency may want to use ITS as a tool for implementing travel demand management strategies with the goal of raising maintenance revenue and protecting the environment. An architecture may accommodate such a policy decision, but in no way forces the decision.

This program only addresses system architecture decisions. (Note: Instances where system design decisions appear in the descriptions of the architectures are only for evaluation purposes.) Ultimately, stakeholders, or their agents, will design systems and implement policies to meet their needs, given the basic guiding principals of an architecture. However, an architecture can foster or deter implementing certain capabilities, technologies, or policy decisions. Therefore, stakeholders should have a keen interest in the architecture framework, since it could be a crucial factor in facilitating or limiting their ITS implementation options.

FEATURES AND DEFINITIONS

In its most generic form, an ITS architecture will have mobile and stationary elements. Mobile elements would include any type of vehicle and individuals with Personal Communication Systems (PCS). Market and technology projections indicate that mobile communication and computer devices are converging into a new series of small, portable products. PCS will provide all kinds of information, including transportation information, to users on the move. Stationary elements of an ITS architecture include, but are not limited to, transportation management centers, roadside equipment (infrastructure), and users with traditional communications (fixed/tethered) in the home or office.

A system architecture determines the interaction among these ITS elements. This interaction specifies what kind of information is passed, where it passes, and the method of that communication. For example, vehicles and other mobile (PCS) users may need to communicate with ITS infrastructure for obtaining real-time traffic information.

An architecture also assigns functions to ITS elements. These assignments determine the distribution of intelligence/processing among ITS components. For example, functions assigned to the infrastructure or mobile units of an ITS architecture require some amount of processing power, communication capacity, and perhaps organizational cooperation.

There are at least two key technical features of an ITS architecture for which definitions and descriptions are useful: Communications and Allocation of Intelligence.

Communications

Communications define how ITS users and providers exchange information. Fixed elements, like infrastructure, can communicate over land-lines and via satellite. Land lines include the common wire telephone lines and fiber optic cables. Cable television and telephone companies have deployed and continue to deploy miles of land-lines. Fiber optic cables offer wideband (high capacity) communications, that offer performance characteristics beyond traditional wire-lines. Closed circuit television is an example of an application requiring wide bandwidths.

The mobile communications field comprises a wider array of evolving options with various cost and performance trade-offs. Mobile communication options allow one-way and two-way interaction between ITS participants. One-way communication is analogous to talking or listening, exclusively. ITS applications emphasize information versus voice communications, but the concept is the same. AM and FM radio broadcasts are examples of one-way mobile communications. A radio broadcast passes information to users without any prompts or acknowledgment. Two-way communications are like a conversation. Cellular telephones are examples of two-way communication applications.

Wireless broadcast is a term that describes a family of communication techniques for passing information (one-way) over large areas, without a physical connection (like a cable or wire). A specific ***wirless broadcast*** technique ***known as FM subcarrier broadcast*** exploits the technical features of a radio broadcast for widely disseminating information. This communications approach, and others like it, might provide a low-cost means for uniformly distributing limited traffic data to many mobile users in a metropolitan area.

Cell-based communications divide a given geographic area into cells, each of which employs a base station and transmitter. The cell size is directly proportional to the transmitter's power. Therefore, the system operator can reduce cell sizes as the volume of communications increases. The net result is a flexible, growth-oriented use of capacity. ***Cell-based communications*** include, but are not limited to, paging and telephone applications. Cellular phones offer a two-way information exchange. ***Cell-bused*** paging techniques pass information (messages) one-way.

Beacons are short-range, one-way or two-way communication devices. Communications between vehicles and infrastructure occur in the vicinity of a beacon, adding position or location-specific content. Infrared, millimeter wave, and microwave technologies can all support localized beacon communications.

As a comparison, ***wireless broadcasts*** and ***cell-based*** communications can provide information over long ranges. ***Cell-bused*** communications include wide area one-way and two-way ***links. Wireless broadcast*** schemes uniformly broadcast information (one-way) to anybody listening. Localized ***beacons*** exchange information over short ranges (on the order of tens of meters). The short-range feature of this technique results in information exchanges at specific geographic locations among users, versus broadcast communication.

Allocation of Intelligence

Architecture alternatives allocate intelligence, which refers to processing and communications power, to different fixed and mobile elements of ITS. The terms centralized and distributed information processing really refer to opposite ends of the spectrum for allocating intelligence throughout a system. Centralized approaches allocate the ***intelligence*** within a few components. A distributed, or decentralized, approach spreads ***intelligence*** over many elements.

For example, an approach to ITS could allocate significant functions and control to transportation management centers for mode and route selection. For individual drivers, a distributed processing philosophy would allot more of this intelligence to individual vehicles. Since the term ***allocation*** of ***intelligence*** may be somewhat abstract, this section includes electronic payment and information collection examples for clarification.

Electronic payment schemes include some specific terminology and offer another illustration of intelligence allocation. Financial identification (ID) cards and prepaid instruments are two basic transaction schemes for electronic payment applications of ITS. These two approaches have different demands on transaction time and user identification at the point-of-sale. Financial ID cards, like credit and debit (e.g., automatic teller machine) cards, require some transaction within the banking sector for settling everyone's accounts after the point-of-sale. Such transaction schemes require user identifications and some amount of time for an immediate account check.

Prepaid instruments typically refer to an electronic purse or ***valuecard*** system. This approach requires a periodic loading of funds or tokens electronically onto a card, eliminating the need for identifying individual users during a transaction and settling accounts afterwards.

Most existing electronic payment schemes use cards with magnetic stripes. ***Smart curds*** denote a technology that incorporates memory, like in a computer, adding special intelligent features. Intelligence enhances both the security and the applications of electronic payment. Both smart card and magnetic stripe technologies apply to either financial identification or prepaid (electronic purse) schemes. The smart card scheme distributes intelligence to mobile users. Magnetic stripe cards require more intelligence within the infrastructure.

Information collection functions include some specific terminology and offer another illustration of intelligence allocation. The concept of ITS depends on collecting information. Current details about the transportation system, including individual vehicles (commercial, transit, and private) and traveler demands, require some sort of surveillance and position location capabilities. Roadside equipment like cameras, radar, and magnetic induction loops (buried in the road) can provide surveillance information. An ITS system architecture may ***also*** encourage the use ***of probes.*** The term ***probes*** refers to using vehicles as sources of data, spreading intelligence over many elements. In-vehicle sensors might also provide information on speed and road conditions.

A vehicle may exploit satellite or more traditional (terrestrial) navigation techniques for locating its own position. The Global Positioning System (GPS) is a constellation of U.S. satellites that provide precise three dimensional position location around the world. Originally deployed as a military system, some GPS capabilities are now publicly available.

RELEVANCE OF FEATURES AND DEFINITIONS

These technical features are not exhaustive of every important detail of an architecture. They do, however, relate to ***stakeholder interests*** and provide a practical starting point for stakeholder consideration.

Consumers

The way an architecture defines communications for various traveler information and advisory capabilities determines the equipment that consumers may need to buy. For example, consumers may need cellular phones, FM radios, or some specialized equipment for ITS benefits. One-way versus two-way communication has potential privacy impacts. One-way communications preclude passing any form of user identification, at the cost of users being able to request specific or specialized information.

The allocation of intelligence for route selection has an impact on the equipment a consumer buys and a user's autonomy while traveling. Route selection within a vehicle requires at least a map data base and possibly expected travel times from the infrastructure. Route selection from a centralized location requires less information processing power in the vehicle.

An architecture's electronic payment framework may allow travelers to use credit cards or bank cards they already have for a wide array of services. However, an architecture may also provide for exclusive or optional use of specialized prepaid cards for specific purposes. Prepaid cards allow for quicker transactions at the point-of-sale, but credit cards and bank cards are widely used for other purchases. Only prepaid cards work without user identifications. Any credit card or debit card system identifies users at the point-of-sale.

Vehicle location and traffic surveillance techniques may impact the equipment a consumer buys. More powerful and capable the infrastructure may result in lower costs of in-vehicle equipment. However, sophisticated traffic surveillance systems (infrastructure) could identify specific vehicles, at least potentially providing law enforcement with user specific information, from speed to location. Consumers should also have an interest in the benefits that an architecture offers for contributing to traffic information collection as probes.

Transportation Infrastructure Providers

Communication between mobile users and the infrastructure is at the heart of the ITS concept of operation for Transportation Infrastructure Providers. An architecture's approach to this communication helps define equipment requirements for deployment. For example, the specific combination, of say, cell-based communications and beacons for long-range and short-range links will define the investment and operations and maintenance requirements for transportation infrastructure providers and affect technical performance. Use of existing infrastructure clearly minimizes deployment costs. Wide acceptance of an architecture's mobile user-infrastructure link among Transportation Infrastructure Providers will impact compatibility across geographic regions.

The allocation of intelligence within an architecture's framework defines the volume of information that Transportation Infrastructure Providers must manage and therefore the scope of their work. Centralization also implies a strong level of coordination among operational institutions and organizations.

An architecture's approach to electronic payment will define important parameters that can help foster product standards and equipment compatibility. Product standards can foster competition, keeping prices down for Transportation Infrastructure Providers. Equipment compatibility helps regions collect fares seamlessly, potentially enhancing revenue. For example, a credit card based system is well understood and widely deployed in other industries. Conversely, a prepaid instrument using electronic tokens versus "real money" could provide freedom from banking regulation.

Lastly, the way an architecture treats information collection (i.e., roadside sensors versus probes) may impact operations and maintenance and the speed of deployment. An architecture that uses existing infrastructure can help control deployment costs for transportation infrastructure providers. Extensive use of probes (sources of data beyond the infrastructure) might reduce operations and maintenance costs for Transportation Infrastructure Providers, compared to extensive use of roadside equipment.

Freight Operations

Communications between commercial vehicles and infrastructure defines the equipment that stakeholders in the freight operations group will need for regulatory compliance and enforcement. For example, the short-range communication necessary for weigh-in-motion applications identify what device(s) or equipment a trucker needs to buy in order to pass weigh stations at mainline speeds. This stakeholder group will also have an interest in compatibility of this communication link across ITS applications and geographic regions. For example, any interstate or long-haul trucker will want his ITS communications equipment to work for numerous user services and throughout his trip.

Where, when, and how carriers move their freight is business-sensitive information. Data archival and processing assignments within an architecture may require access controls over that information, to assure that freight operations stakeholders are comfortable with the architecture and participate in ITS.

Standards and compatibility for electronic payment across ITS applications and geographic regions impacts the way carriers do business. For example, truckers do not want multiple electronic "tags" to exploit ITS capabilities, like electronic toll collection, through several states.

Lastly collecting traffic information, within a particular architecture framework may raise concerns over user or vehicle identification. Knowledge of a particular vehicle's speed, location, and identity impact perceptions of labor's privacy, law enforcement capabilities, and the security of business-sensitive data.

Public Safety Services

There are two ITS applications of mobile communications that are most important to this stakeholder group. Mayday communications will define important equipment needs and institutional links associated with public safety services stakeholders. Communications between dispatchers and fleets will also highlight equipment needs. Both mayday and dispatcher-fleet links will impact requirements for standards and compatibility issues across geographic regions.

The allocation of intelligence for fleet management can underscore the concept of operation for ITS to this stakeholder group. Specifically, an architecture will identify organizations, institutions, and jurisdictions that could work cooperatively. For example, an architecture may create a mechanism for linking a public, emergency fleet management center with a privately operated traffic control/information center.

Passenger Operations

Stakeholders in the passenger operations group who understand the communication link between vehicles and infrastructure will also understand the equipment they need for many ITS applications. Specifics about this communication link may also help highlight standards and compatibility issues. Communications also determine the extent of intermodal information dissemination to travelers. For example, an architecture that fosters dissemination of intermodal information through telephones, on-line computer services, cable television, kiosks, vehicles, and personal communication systems could help improve transit ridership.

The allocation of intelligence for fleet management can underscore the concept of operation for ITS in a given stakeholder's business. For example, ITS communications from a fleet management center might enhance the way transit operations currently work. However, an architecture may channel more information directly to individual transit drivers, to help stay on schedule, allowing drivers the chance to make better decisions while on their routes.

The electronic payment function of an architecture impacts fare collection. Different approaches may maximize compatibility across ITS applications and geographic regions, fostering ridership. For example, a single payment card that works for major transit bus, rail, and taxi services throughout a metropolitan area could enhance the convenience and attractiveness of transit and para-transit service.

Passenger operations stakeholders should also have an interest in the role their vehicles and fleets play in traffic information collection as potential probes. Transit vehicles and taxis are examples of potential probe resources, given their travel along many metropolitan roadways. An architecture will define the potential benefits for contributing as a probe.

Product and Service Providers

Product and Service Providers have a strong interest in virtually every detail of a system architecture. For example, details concerning all communication links (fixed and mobile) help identify an array of potential products and services for ITS users.

An architecture's allocation of intelligence will tend to foster a mix of product and service-oriented markets. For example, infrastructure-based route guidance and selection could create a stronger service-oriented market for individual users, while a vehicle-based approach could encourage a more product-driven market for vehicles and other mobile users.

Electronic payment structures and information collection techniques (including vehicle location functions) that an architecture offers will also provide valuable insights into markets and products.

ARCHITECTURES-OVERVIEWS

The four architecture development teams each have a distinct approach. The summaries in this section provide consise, five-page overviews of each approach. The subsequent six sections summarize the architectures from specific stakeholder perspectives. These summaries appear exactly as the architecture development teams provided them. U.S. ***DOT and ITS AMERICA have not verified or endorsed this informtion.***

Architecture Development Teams

HUGHES | LORAL | ROCKWELL TEAM

Hughes Aircraft	Loral Federal Systems	Rockwell International	Westinghouse Electric
• Delco Electronics	• Ameritech	• Apogee Research	• Bell Atlantic Mobile Systems
• Electronic Data Systems	• Louis Berger & Associates	• California PATH	• Calspan
• General Motors	• New Jersey Highway Authority	• California DOT	• Florida DOT
• Hickling	• Oakland County Michigan Road Commission	• George Mason University	• Frederic R. Harris
• JHK & Associates	• Siemens	• GTE Laboratories	• Harris Corporation
• Michigan DOT	• University of Michigan	• Honeywell	• Maryland DOT
• Minnesota DOT		• Iowa State University	• University of Florida
• Sprint		• New York State DOT	• Washington State DOT
• University of Minnesota		• Texas DOT	
		• Texas Transportation Institute	

HUGHES

OVERALL PHILOSOPHY

The travel environment should be "user-friendly". Travel should be pleasurable and easy. The ITS architecture should offer the opportunity to greatly reduce the stress and tension currently associated with travel. Consider as examples: being able to find your freeway exit on a dark rainy night by listening for an announcement in the vehicle; enjoying a driving vacation without getting lost; getting assistance from high technology to prevent an incipient accident.

The travel environment should be "user-useful". Travel should be efficient. The architecture should minimize the time wasted on problems that would not be tolerated in other areas of our lives. Consider as examples: knowing how long to allow to get across town to a meeting; knowing in real-time the location of a cargo shipment involving multiple carriers; or hearing only those travel advisories which are pertinent and being able to ask for a replay of the advisories.

Demand pricing, and specifically road pricing should be accommodated. The architecture should allow road pricing to be installed on existing freeways without requiring extensive construction work.

The vehicle should be incorporated into the agency's infrastructure so that the real-time road data that the vehicle can provide is made available to the agency and returned to the driver as traffic information.

Driver privacy and autonomy should be inherent in the architecture. The public guards its traditional rights in this area. Any architecture that challenges these rights would jeopardize its chances of being accepted. The benefit to society versus benefit to the individual is not a necessary trade-off; the architecture can be designed to accomplish both.

A distributed architecture is the best choice for systems such as ITS. This type of architecture is more robust, and provides higher throughput and greater processing power than a comparably priced centralized approach.

An open architecture is the best approach to obtain a system that is extensible, can mix new and old technologies, aids incremental installation and can interface with systems belonging to other agencies. Incremental installation permits the tax payers to experience benefits immediately, building their support for continued funding.

ARCHITECTURE OVERVIEW

The application of the Hughes Team Architecture to travel and traffic management, basic to the needs of all Stakeholders, is shown in Figure 1. The Figure emphasizes that the Architecture specifies a tag/beacon approach to Vehicle-Roadside Communications and that vehicles of all types are equipped with tags so that they can take advantage of the traffic advisories provided by this application of the Architecture. The same tag/beacon approach is applied to many Stakeholder-specific applications of the Architecture. An alternative implementation is the "virtual" beacon, described below.

The Architecture recognizes that the vehicle "knows" a lot about the road environment, can be an important source of data for the traffic manage-

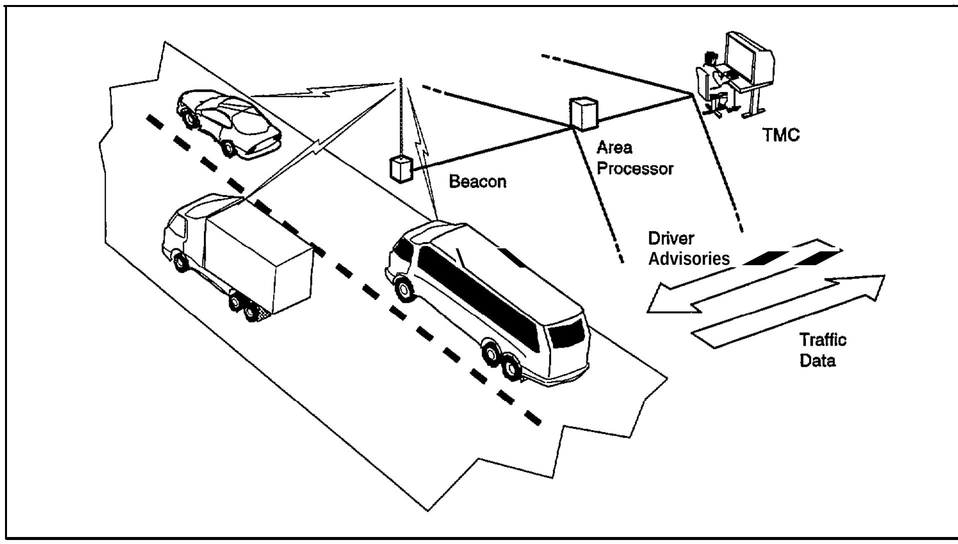


Figure 1. The Basic Hughes Team Architecture

ment system, and is considered to be an extension of the infrastructure. The vehicle can provide the Traffic Management Center (TMC) with current travel times (probe data), speed profiles, road surface conditions, and visibility data. In return, the vehicle receives pertinent travel advisories from the TMC.

The TMC monitors summary data originating from vehicles, static sensors, and cellular phone calls and performs a continuous assessment of the traffic situation. It detects and evaluates traffic incidents and mitigates congestion by issuing real-time-traffic information, routing parameters and driver advisories and by controlling ramp metering and traffic signal timing. The Area Processors control the landline communications between beacon and TMC, providing redundant paths. The Area Processors have the capability, in case of a TMC failure, to perform a minimal set of TMC operations or to switch to a back-up TMC in a neighboring jurisdiction. The beacons are installed at road-side locations selected for traffic monitoring and for driver advisories. (The discussion of beacon locations is discussed below.)

The communications between vehicle and traffic management infrastructure must be done at locations specified by the TMC. For example, a traffic advisory warning of an incident must be transmitted to vehicles approaching the incident, but at a location, such as at a freeway off-ramp, where an alternate route can be taken. Travel time measurements must consistently be made between specified road locations so that the TMC can recognize anomalies.

Location-specific communications are required for a number of the Stakeholder-specific applications, as illustrated in Figure 2, where the desired communication zones are shown as shaded rectangles. The location for performing electronic toll collection communications must be on the mainline in parallel with the manual toll booth lane. The location for commanding a commercial truck to pull off into the weigh-station must be just before the turn into the weigh station. The location for informing a bus of its performance to schedule must be at a bus stop.

There are two complementary implementations of the location-specific communications link, see Figure 3. The "fixed" beacon provides two-way, very short range, high bandwidth communications with inexpensive transponders, called "tags" in vehicles passing within 100 feet of the beacon. The beacon is an inexpensive combination of a PC type computer and a short range radio transmitter/receiver and is installed at locations along the road. The beacon computer is programmed to perform any combination of the location-specific communications, and to process the data collected from both passing vehicles and local static vehicle sensors.

The "virtual" beacon does all of the functions of the fixed beacon, but does not require any traffic management infrastructure. It requires the vehicle to be equipped with a cellular phone, a GPS receiver, and associated processing. In this implementation, the vehicle's cellular phone automatically calls the TMC, gives its GPS location, and receives instructions from the TMC instructing it to call the TMC back when it reaches a specified location. When the vehicle reaches the specified location it automatically calls the TMC. The vehicle and infrastructure then communi-

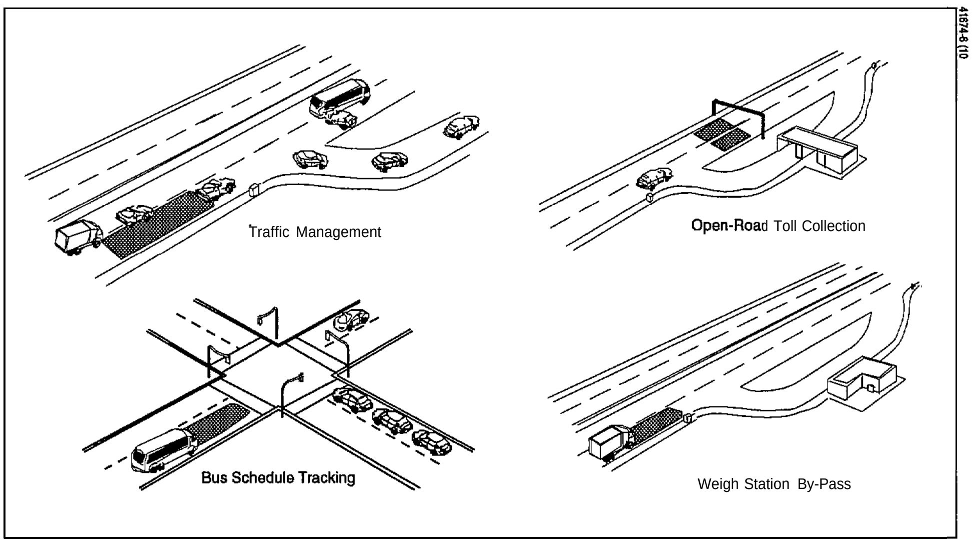


Figure 2. The Concept of "Location Specific" Communications

cate as though a tag is in the vehicle and a fixed beacon is at the location. The TMC can then instruct the vehicle to call at a subsequent location. The virtual beacon enables the TMC to dvnamicallv reconfigure the system, shifting beacon coverage to dynamically provide more detailed coverage of an incident, a disaster area, or a special event. The virtual beacon enables an agency to implement an Architecture initially without any infrastructure cost.

The route guidance vehicle contains a PC type computer which is programmed to select a route between the vehicle's current location and a desired destination, and then to guide the driver along that route. The

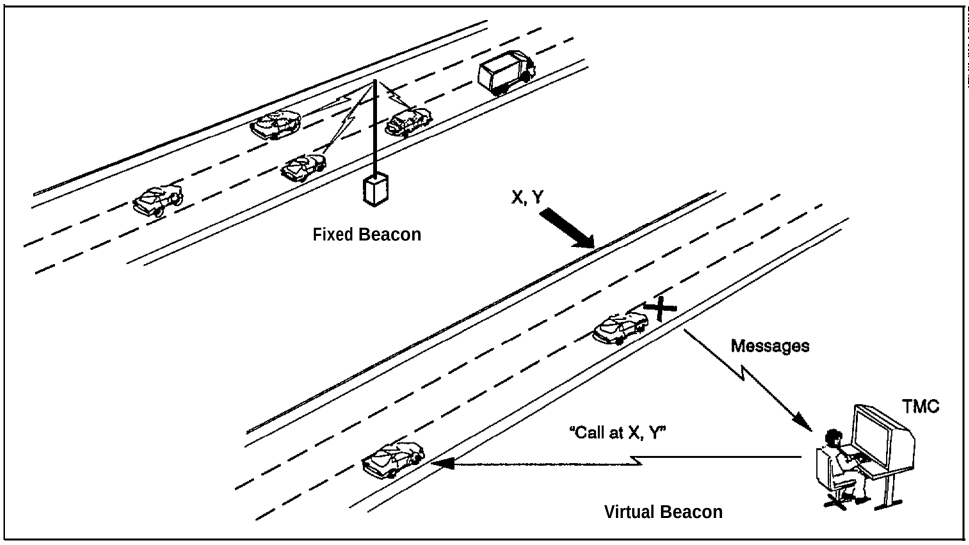


Figure 3. The Two Implementations of Location-Specific Communications

route selection could also be done as a service at a centralized location, such as at a TMC, and then transmitted to the vehicle for use in route guidance. However, the Hughes Team believes that it is risky to assume that such a service would be available nationally and for that reason, plus the privacy issue, in-vehicle route selection is the standard. Real-time traffic information is broadcast area-wide to enable route selection programs to avoid congestion.

Commercial vehicle, emergency vehicle and taxi fleet operations are usually under the control of a dispatcher. The fleet operator can chose to either do the route selection at the dispatch center, or to have each vehicle do its own selection.

Figure 4 shows the relationship between the Traffic Management System and other management systems. Real-time traffic information (RTTI) is used not only by route guidance selection programs to create routes which tend to avoid traffic congestion; it is broadcast area-wide and received by route guidance vehicles, kiosks, and by route selection service providers.

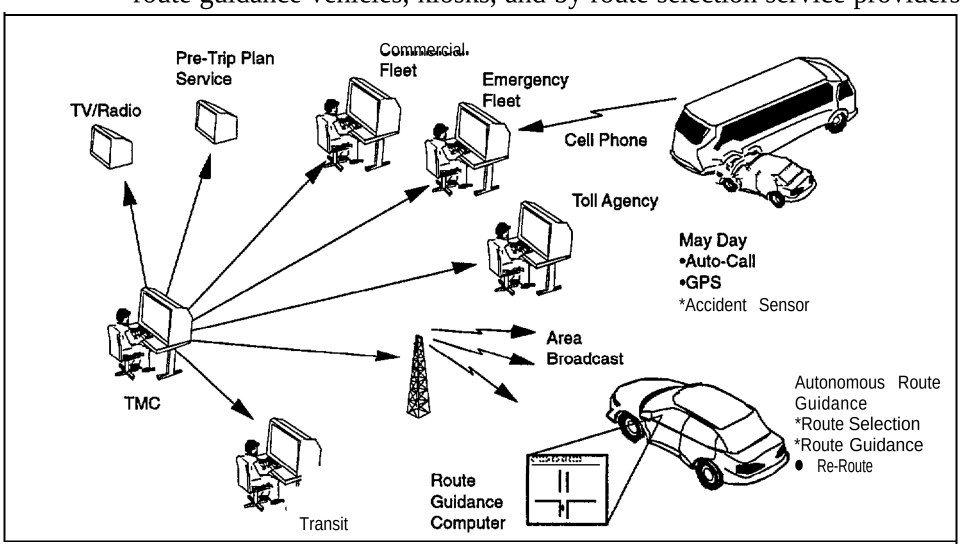


Figure 4. The Role of the Traffic Management Center in the Architecture

ASPECTS OF THE PHYSICAL ARCHITECTURE

The Hughes Team Architecture is characterized as being flexible, distributed, fine-grained, robust, and protective of privacy.

Flexibility is a product of the modular implementation of the Architecture, the open interface standards, and infrastructure independence. The significance of the modularity is that an implementer of the architecture can easily specify the modules required to build a system to meet his needs, as though he were ordering components from a catalog. Open interface standards enable the architecture implementer to interconnect current equipment, newly defined ITS equipment, and equipment that has not even been defined yet. Infrastructure independence allows the equipment being interfaced to be transparent to the rest of the system; for example, real-time traffic data is broadcast for reception by route guidance vehicles, but is also received and used by kiosks which generate routes for travelers.

The Architecture is distributed in two senses: Functions are distributed to where the data is generated. For example, a processor in the vehicle evaluates the traction-control data to determine if the vehicle should report slippery road surface, and the beacon analyzes the data from many vehicles to determine what gets reported to the area processor, etc. Secondly, information is distributed to where it is needed; for example a traffic advisory is sent to the beacons up-stream of the incident.

The Architecture is fine-grained in the sense that it deals with specific road-side sites and vehicles passing these sites. This enables the system to be faster and more accurate in detecting and mitigating incidents, and in providing passing vehicles with the specific information they need. Toll collection and commercial vehicle by-pass operations also occur at precise locations.

The Architecture is robust because of two aspects: The distributed architecture is designed to have no single-point-of-failure. Another way of saying this is that the Architecture “fails soft”. When an element fails, system performance may degrade, but the system does not fail. As examples: the loss of a beacon will simply mean that the traffic probe data is more coarse in this area; the loss of the TMC will result in the associated area processors taking over a limited decision making function from the TMC. The other aspect of the robustness is the Architecture’s ability to reconfigure the system in real time by “calling in” virtual beacons to provide coverage where fixed beacons or associated communications have failed.

The Architecture has been designed to insure the privacy of driver and vehicle owner. Tag/beacon-infrastructure messages do not reference driver or vehicle identification. Route guidance vehicles select their own routes and guide themselves to their destination without reporting location or destination to the TMC. Exceptions are commercial vehicle operations, bus tracking and some implementations of electronic toll collection, where the point of the application is vehicle identification.

LORAL

The Loral Team Intelligent Transportation System (ITS) Architecture is a set of independently deployable subsystems. These subsystems are designed to cooperatively work together, using open interfaces, to achieve the overall goals of the ITS program and implement all 28 of the User Services.

The Loral Architecture provides:

- Achievable evolution to full deployment of all ITS User Services
- Choices for users and providers of the User Services
- Incentives for public, private, and individual participation

The principles of our Architecture are based on a simple fact: ***each city, town, village and rural area in America is unique.*** And, while most of them share some problems in common, it is their differences that require a system that can adapt to the individual needs of each community. Thus, the Architecture is flexible and adaptable.

The Loral Architecture is based on the concept of a ***Fully-Integrated Transportation System.*** Multiple sources gather information which is processed and disseminated to a variety of users. Each transportation system element (traveler, agency, company, vehicle, etc.) has access to all of the information it needs to perform its function in the best possible way.

The key providers of the ITS User Services are:

- Transportation Management Centers (TMC), which provide Traffic Control, Incident Management, Demand Management, and System Planning
- Independent Service Providers (ISP), who provide services such as Trip Planning, Traveler Information, Route Selection, Yellow Pages Information, and Dynamic Ridesharing
- Public Transit Centers (PTC), which provide public transit in its various forms: buses, rail, subway, paratransit, etc.
- Emergency Management Centers (EMC), which provide MAYDAY response, emergency vehicle management, and an interface to E-9 11 services

The key users of the ITS User Services are:

- Travelers, who include commuters, business users, vacationers, and special needs individuals
- Commercial Vehicle Operators and Commercial Fleet Managers
- Government Agencies, including city, county, state, and federal. These include Transportation Infrastructure Providers and Planners, as well as Public Safety Agencies such as police, fire, and emergency medical services.

- Interest Groups such as environmental, safety, and consumer advocates.

The Loral Architecture defines how the User Service Providers and the Users are connected (See Figure 5).

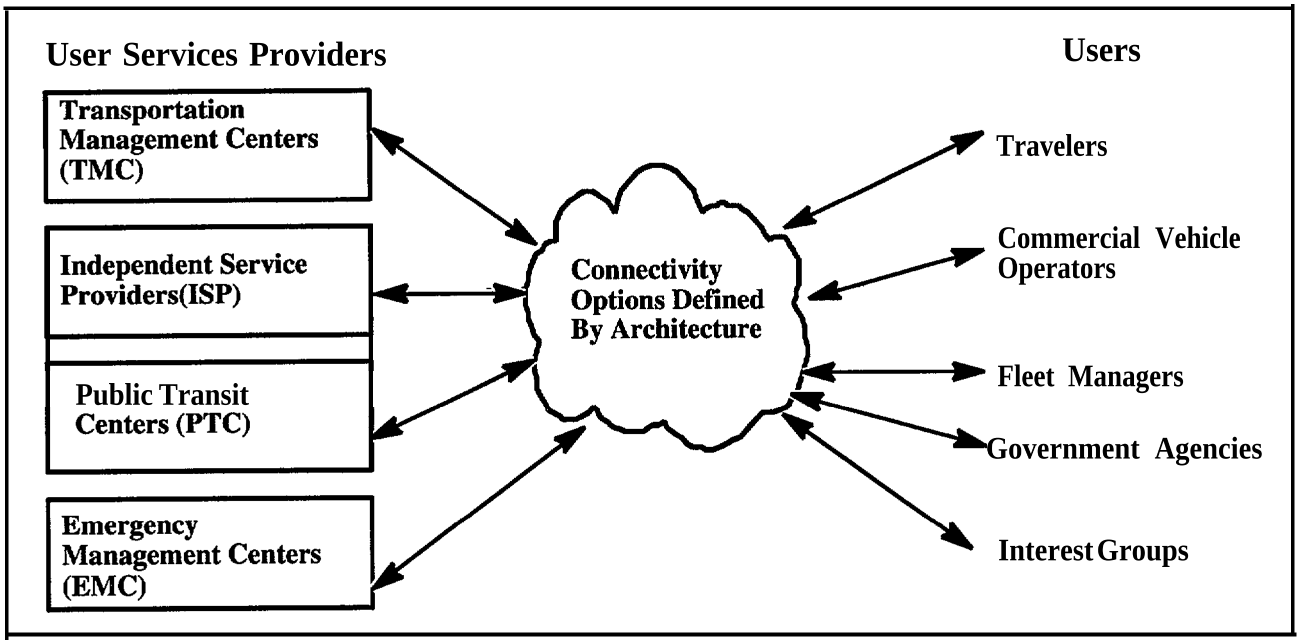


Figure 5. The Loral Architecture Links User Service Providers to Users

Achievable Evolution to Full Deployment of All ITS User Services

The Loral Architecture provides a low risk achievable evolution from initial to complete deployment of all 28 User Services. To achieve this evolution, the Loral Architecture has incorporated the following features:

Provides modular and flexible subsystems. The Loral Architecture is modular in design to adapt to the individual needs of each community. The modularity allows individual elements to be added, subtracted, or altered, as needed for flexible deployment,

Supports open standardized interfaces. The Architecture is based on the use of open, standardized interfaces designed to provide national compatibility (one system works everywhere in the country) for key components of the architecture and to reduce the market entry risk for product and service providers. Because of the standardized interfaces, all subsystems in the Architecture will support a range of existing or anticipated offerings from a wide range of product or service providers.

Accommodates increasing levels of subsystem integration. The Loral Architecture supports the introduction of new technologies and takes advantage of them to provide ever higher levels of subsystem integration, which will lead to higher system performance. The Architecture supports such advanced concepts as linking route selection and traffic control.

Maximizes use of existing and planned Infrastructure. The Architecture ensures that the existing transportation infrastructure can be integrated into the deployment of new User Services. Minimizing the public sector deployment costs is a key feature of our Architecture: this is accomplished not only through use of existing infrastructure, but through encouraging private industry participation in providing many of the User Services.

Communications is also a critical aspect of ITS deployment. The Architecture uses existing and emerging communication services (such as the “Information Superhighway”) to achieve rapid evolutionary deployment with little new capital investment for ITS unique communication needs. A national communications infrastructure to support ITS would be costly to deploy if it were only to be used for ITS. Use of existing wireline communications leverages the considerable infrastructure already developed by telecommunications companies. By using existing and emerging wireless communication services, the Loral Architecture avoids a dependence on the FCC to allocate additional spectrum for ITS.

Provides locally determined demand management capabilities. Demand management is a critical option for some areas to control congestion or reduce pollution while maintaining transportation system services. The Loral Architecture offers many options that assure efficient use of the limited transportation resources. Some of these options include signal priority, lane access permissions for different classes or occupancies of vehicles, and flexible transportation pricing policies.

Choices for Users and Providers of the User Services

The focus of the Loral Architecture is on providing User Service choices. User choices for travel modality selection, desired services, and privacy. Service provider choices for degree and timing of deployments and implementation of policy. Our Architecture recognizes that individual and community needs vary, by offering choices that can reflect these unique needs.

Provides ***user choices.*** Modal choice is facilitated with the real-time information provided on all modes of transportation. ISPs provide trip planning services that can be generic or personalized, providing plans and ticketing across all transportation modes. Users can choose among modes based on cost, convenience, and other needs.

Many equipment options are supported for both individual and commercial users. These implementations provide varying levels of performance with associated levels of cost to the user. By placing many services in the private sector, the Architecture fosters competition between multiple companies to meet the needs of their customers.

The Loral Architecture also provides users with privacy choices, from anonymous fare transactions to highly personalized travel planning. Users voluntarily relinquish privacy only when the services they desire require personal information. Our Architecture also takes great care to maintain the security of all data, through encryption and access control measures.

Offers choices to serviceproviders. The Loral Team recognizes the uniqueness of each region's needs. Those in the public and private sector who provide User Services are offered many choices by the Loral Architecture. The Architecture is modular, allowing phased or selective deployment schemes. The Architecture accommodates existing infrastructure, to allow service providers to protect their investments. And finally, the Architecture allows the implementation of regional transportation policies: high occupancy vehicle (HOV) lanes, transit pricing, ridesharing, emissions attainment and many other regional concerns can be addressed in the locally appropriate manner.

Incentives for Public, Private, and Individual Participation

The ITS National Architecture will only be successful if it gains the acceptance of the public sector, private industry, and individual travelers. The Loral Team has developed an architecture which provides incentives for participation by all of these important groups through the following features:

Provides low entry cost. Travelers will get individual benefits from the Architecture infrastructure at no cost through variable message signs, commercial AM/FM/TV/Cable channels, highway advisory radio (HAR) and their personal computers that will be hooked up to the on-line services.

Users can electronically pay tolls and fares with a low cost toll tag. Commercial truckers will be able to drive past weigh stations using only their ID tags. Travelers will reap the benefits of improved transit operation, more available information, and added transit security as part of the public transit features of the Architecture. Widely available paratransit (flexible route transit) will provide flexibility to travelers at a low cost. These latter public transit features will provide incentives for increased ridership.

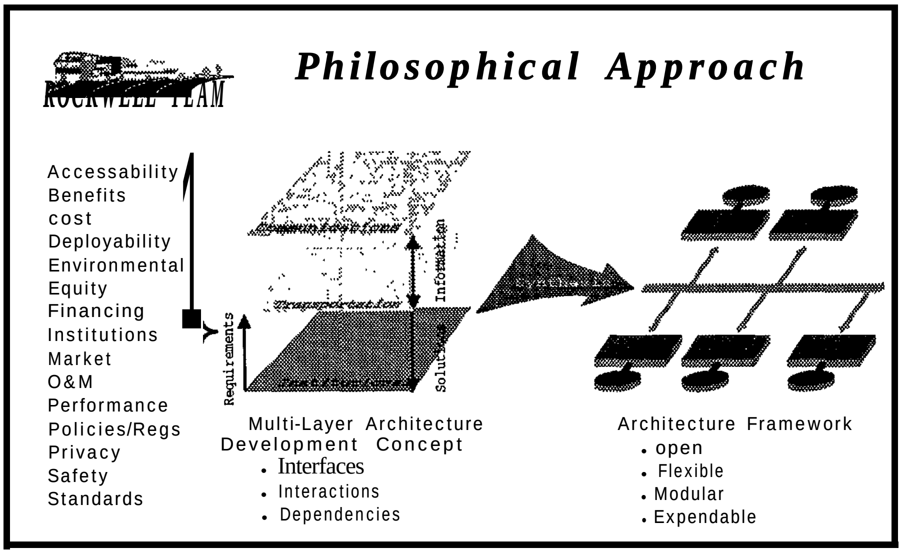
Accelerates early deployment opportunities for product and service providers. The Loral Team believes that a competitive free market is the best mechanism for allowing travelers to get the services and products that they want at the lowest prices. To encourage a free market for the delivery of travel services, the Loral Architecture has defined a private sector Information Service Provider (ISP) subsystem with standard message interfaces to 1) the public sector Transportation Management Centers (TMCs), 2) other fixed subsystems, and 3) their traveler clients located at home, at an office, at a kiosk, or in vehicles. ISPs will have opportunities to compete for customers by differentiating themselves through the quality and type of the information processing that they perform to provide travel services. Price performance differentiation will be possible by how successful ISPs are in reliably identifying the "best" multimodal trips, vehicle routes, ridesharing matches and/or other services for their clients. ISPs may specialize in services for a specific class of traveler (e.g. commercial trucker, HAZMAT trucker, vacationer, commuter) or the geographic scope that they cover (regional vs national). This arrangement provides incentives for industry to provide services, and incentives for travelers to use the services.

Encourages funding equity By splitting the key ITS infrastructure elements between private and public entities, the Loral Architecture is able to assure equity in expenditures/payments. Public funds are used by public agencies (running TMCs and Roadside facilities) to benefit all travelers equally, and private funds (and fees) are used to supply additional "value added" services to individuals willing to pay for those benefits.

Avoids new legal liabilities for public transportation infrastructure providers. The Loral Phase I research has found that public agencies wish to focus on their traditional roles of incident, traffic, and demand management. Personalized services are best offered by the private sector. This is especially true where liability may become a factor, since the private sector has mechanisms for dealing with liability not available to the public sector. New services that are considered to be potentially high liability risk areas such as advanced vehicle control, and in-vehicle signage are assigned to privately operated subsystems. The Loral Architecture provides incentives for public sector participation by mitigating their new liabilities.

ROCKWELL

The Rockwell Architecture Development Team is a public-private partnership between State Department of Transportation (DOT) agencies, private industry, and academic institutions. It embodies the same type of partnership that will be required to develop, implement, and deploy future ITS products and services. Its members represent the diverse views, values, sensitivities, and needs found across America. As a result, the Team's architecture is designed to be open, unbiased, and above all, flexible. Like the Team, the architecture reflects a National perspective.

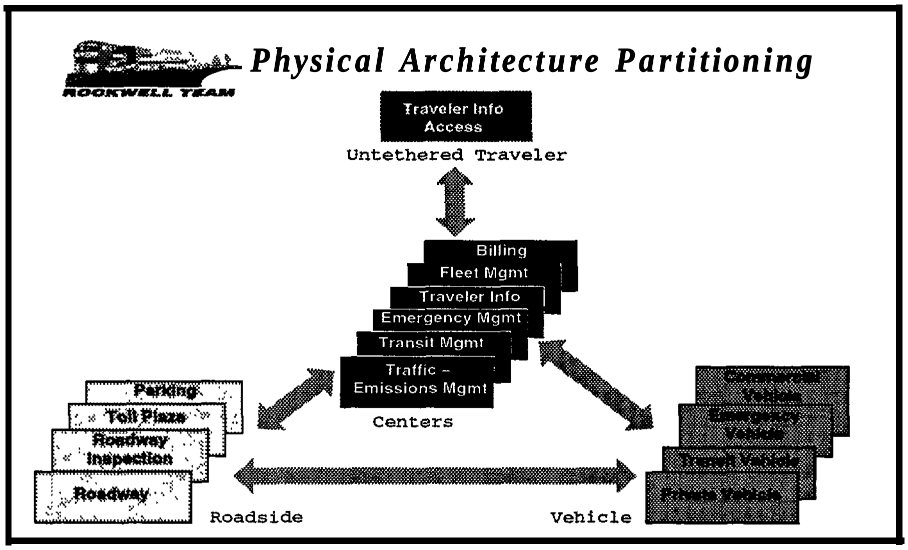


The architecture defines the interfaces and the interactions between three complex entities, represented here as three layers. These layers are the Institutional Layer, Transportation Layer, and the Communications Layer. The Institutional Layer includes public agencies, private industry, and the consumers. It reflects the policies, regulations, and differing socioeconomic requirements and constraints levied by urban, interurban, and rural settings. The Transportation Layer includes the infrastructure and vehicles, as well as all of the transportation relevant entities (e.g., Roadways, Vehicles, Travelers, Buses, Commercial Vehicles, TMC's, etc.) required to implement and utilize user services. The Communications Layer connects the users with other users and with the service providers. It includes information management and all of the communications entities, including wireline and wireless systems and components.

INSTITUTIONAL LAYER DEFINES REQUIREMENTS/CONSTRAINTS

The Institutional Layer defines the requirements and the constraints. The Transportation Layer proposes solutions to satisfy these, and the Communications Layer provides the means to transmit control instructions and exchange data between the Transportation Layer entities. Of the three layers, the Institutional Layer has the greatest sway over whether or not a user service is accepted. As such, analysis of Institutional issues has played a major role in defining the Rockwell Team Architecture.

From the results of the analysis of user services, the Transportation Layer has been partitioned into four system categories and fifteen subsystems. This partitioning results from the grouping of functions that are within the same jurisdictional boundary aud perform a similar function, or have their functionality residing in the same location. The most obvious example is the grouping of the Private, Transit, Emergency, and Commercial Vehicle subsystems in the Vehicle system category. The other system categories are the Centers, Roadside, and the Untethered Traveler. The grouping of functions into systems and subsystems enables flexibility in system design implementation and the incremental deployment of products and services.

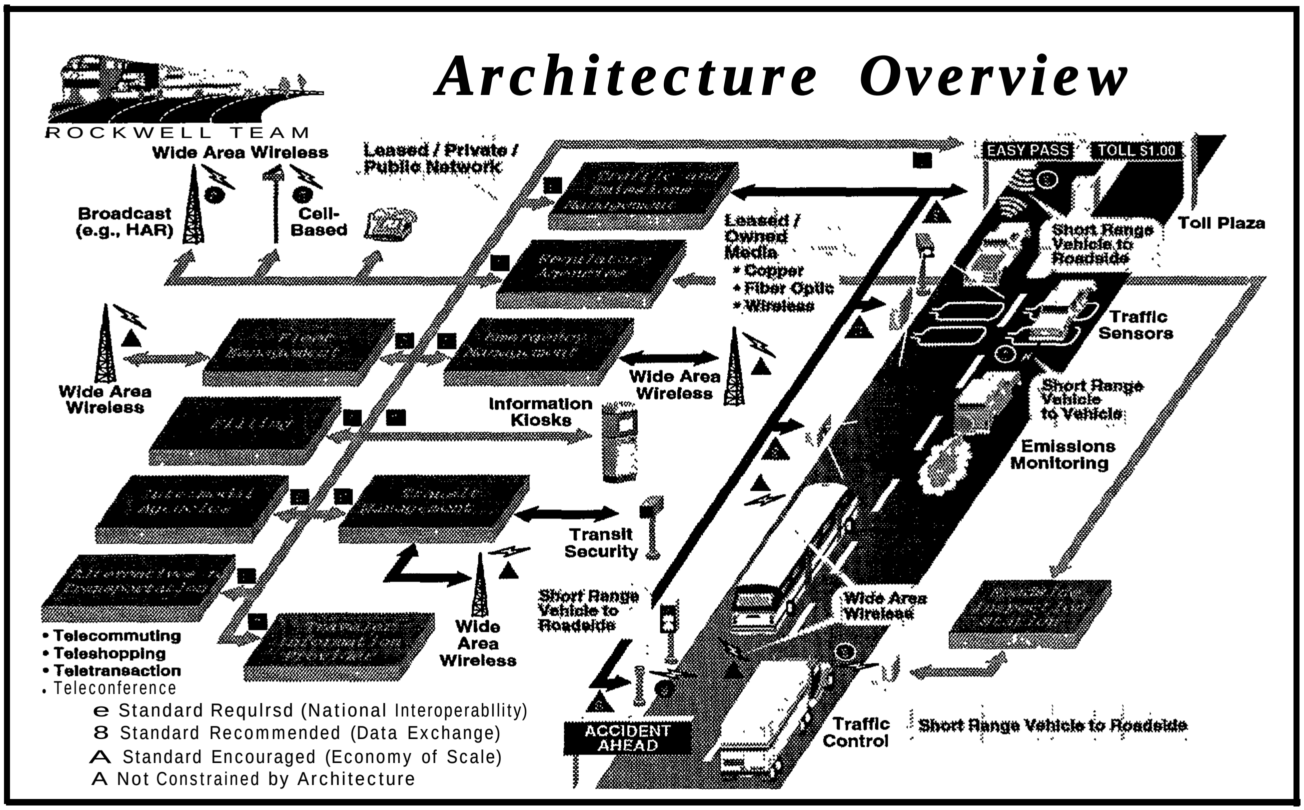


An overview of the Rockwell Team architecture is presented below. Elements of the Transportation Layer, shown on the left side of the graphic, are linked over a leased, private, or public network, such as the public switched telephone network (PSTN) or the National Information Infrastructure (NII). As shown, interface standards are recommended at the application layer of each interface to facilitate access to the information stored in the distributed databases. The specific database structure is a local concern and does not require a standard. The format of the data can be converted or "filtered" to comply with the network format. Security requirements to control access to the database are required, however, to protect proprietary or personal information.

The Transportation Management Center (TMC) is the major building block in an urban/interurban area. It contains four of the six subsystems that make up the Center system category. They are the Traffic and Emissions Management, Transit Management, Emergency Management, and the Traveler Information Provider subsystems.

In the Rockwell Team architecture, the Traffic and Emissions Management subsystem is responsible for traffic monitoring/management, demand/congestion control management, toll plaza operation, and the measurement of emissions. The Transit Management subsystem is responsible for transit operations planning, passenger and fare management, passenger security, and maintenance for buses, paratransit vehicles, and light rail. The Emergency Management subsystem automates the notification and coordination of emergency vehicle response following the verification of an incident, its location, and the nature of the emergency. The Traveler Information Provider subsystem provides information and services to travelers and the media, including pre-trip and en route information, route planning with updates based on traffic conditions, incident notification, parking management, and Mayday support.

The Fleet Management subsystem manages fleets of commercial vehicles, such as long and short haul trucks and taxis. It is responsible for vehicle tracking and dispatch, material tracking, credential checks, and automatic safety inspections. These subsystems are connected to Regulatory Agencies, the Billing subsystem, which provides the capability to combine the electronic payments used by the various transportation modes into a single integrated subsystem, and other intermodal transportation agencies, e.g. port authorities, airports, and rail, over the leased, private, or public network described earlier. As long as these subsystems adhere to a common interface standard at the application layer, the architecture is not concerned with how they are designed or configured.



MAINTAINS JURISDICTIONAL AUTONOMY

The TMC establishes an interface between the various modes of transporting people and goods, integrating and coordinating actions through the sharing of information. The architecture supports the collection, integration, and dissemination of information by the TMC. It does not prescribe who has control. This decision is left up to the local jurisdictions allowing them to maintain their local decision making autonomy, yet still benefit from coordinated action through prearranged institutional agreements.

DOES NOT PRESCRIBE DESIGN

The architecture does not prescribe how the TMC is designed or configured. Its elements may be co-located, located in different buildings, or even in different geographical areas. The architecture is not restrictive. A jurisdiction may choose to distribute or decentralize management and control functions, or it may choose to centralize them for reasons specific to its requirements.

The TMC gathers information through roadway sensors and from vehicle probes. These data can be sent directly to the TMC or aggregated at HUBs or controllers. The architecture builds upon and leverages off of the existing infrastructure. Data exchanged between the roadway and the TMC, such as control signals, emissions measurement data, traffic congestion data and video incident confirmation imagery, is carried over leased or owned media. The architecture supports all of the currently used methods, including copper (unpaired conductors, twisted pair, and coaxial cable), fiber optics (multimode and single mode), and wireless (microwave, cell based, and spread spectrum). The architecture does not require a roadway to TMC standard at the national level.

ALTERNATIVES TO TRAVEL ACCESSED THROUGH NETWORK

Alternatives to making a trip in the first place are available over the same network used to connect the Transportation Layer entities. For instance, a traveler could use the network to gain access to teleconferencing, telecommuting, teleshopping, teleeducation, and teletransaction capabilities from the home or the office. These same services will one day be available over personal data assistants (PDA's).

The Communications Layer of the Rockwell Team's architecture is based on the existing and emerging communications infrastructure. It consists of four interfaces that tie the user with service providers or other users. The four interfaces are a wide area wireless interface (broadcast and cell-based) and a short range vehicle-to-roadside (VRC) interface for communications between mobile entities and fixed sites, a short range vehicle-to-vehicle interface for communications between mobile entities, and a wireline (landline) interface for communication between fixed entities.

WIRELESS COMMUNICATIONS STANDARDS REQUIRED

For nationwide interoperability, the architecture requires that a standard communication interface be defined for all interfaces to a vehicle. A single standard is required for all beacon based short range vehicle-to-roadside interfaces (e.g. toll payments, in-vehicle signing, automated parking payment, roadside inspection, and credential checks). It is recommended that current standards activities be adopted and extended to include all of the beacon type data exchange requirements. A separate standard is required for the short range vehicle-to-vehicle interface.

Standards are also required for wide area wireless communication, both broadcast and cell-based. Broadcast transmissions would be used for one-way transmissions, such as traffic reports. Cell-based transmissions are two-way. Examples include yellow page inquiries and requests for routing instructions. The major requirements for the wide area wireless component of the Communications Layer are that it must be ubiquitous and it must provide seamless service. FM-subcarrier is a candidate for broadcast. CDPD is a leading contender to meet the cell-based requirements. ESMR is a serious contender. Market forces will determine which one comes out on top.

FLEET VEHICLES RETAIN EXISTING COMMUNICATIONS

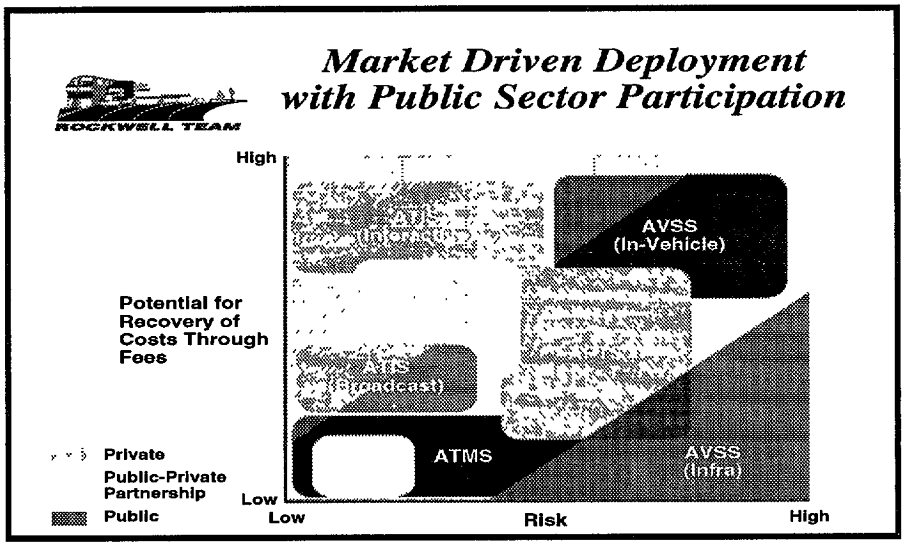
It is important to note that the architecture does not require all vehicles to adopt the national standard for wide area wireless communications. Not all vehicles need to have national interoperability. Examples include transit, law enforcement, fire, taxis, and short haul delivery trucks. Under the Rockwell Team architecture, these vehicles can continue to operate using their current wireless systems. The same holds true for long haul trucks. The architecture does not require these trucks to replace their current wide area wireless communication systems. It does require that they adopt the short range vehicle-to-roadside communications standard if they wish to take advantage of the ITS commercial vehicle operations user services.

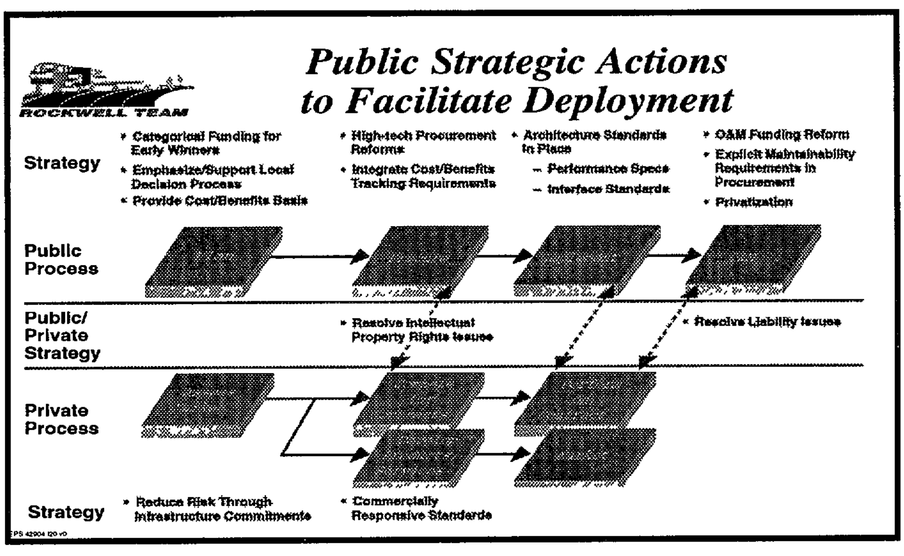
Nationwide deployment of ITS user services will result from a multitude of local deployment decisions by individual public agencies and the private sector. The Rockwell Team architecture maximizes the choices for each of these implementors by restricting its scope to include only those interface definitions and functional descriptions required to ensure interoperability. This flexibility empowers each implementor to make maximum use of existing assets and provides a variety of evolutionary paths for maturing ITS capabilities based on individual priorities and local policy. Active participation by both public and private sectors will be required.

Deployment Strategy Balances Market Forces

The Rockwell Team deployment strategy strikes a balance between a laissez-faire, completely market driven deployment strategy, and one that relies on public sector intervention at each step of the deployment. A market analysis has been performed for each of the identified ITS services to determine their attractiveness to private sector participation and investment. The market analysis was based on an assessment of relative risk and the potential for recovery of costs through fees for each service. As a result of this study, ITS user services were classified as public or private, with a large number of services in the middle ground that may be either public, private, or delivered through a public/private partnership.

A variety of strategic actions are required to facilitate the public sector initiatives, private ventures, and creative public/private partnerships that will result in the deployment of ITS. Key actions include the timely establishment of enabling standards, policy guidance to mitigate potential institutional roadblocks, and specific strategic investments to ignite ITS deployment. The public and private sectors have different motives and significantly different processes which must be recognized in planning deployment.





The Rockwell Team Deployment Strategy places early emphasis on a balanced set of core services that can be adapted to regional requirements and form a basis for more advanced services to follow. These early deployment candidates include: Traffic Monitoring and Management, Broadcast ATIS, Transit Vehicle Tracking, Passenger and Fare Management, Credentials, Mayday/Emergency Response, and Electronic Tolls.

The selected services provide tangible efficiency, productivity, and safety user benefits to a wide range of ITS stakeholders and the public at large. These basic services will be complemented by advanced traveler information products and services (e.g., in-vehicle route guidance systems and interactive traveler information systems) that will be increasingly offered by the private sector over the next five years.

WESTINGHOUSE

The Westinghouse Team has formulated it's ITS Architecture into a set of eight physical systems connected together by a flexible communications infrastructure, as shown in figure 6. This overview briefly describes the eight systems, initial cost estimates, our evolutionary deployment strategy, and the key performance improvements obtained with a typical urban deployment.

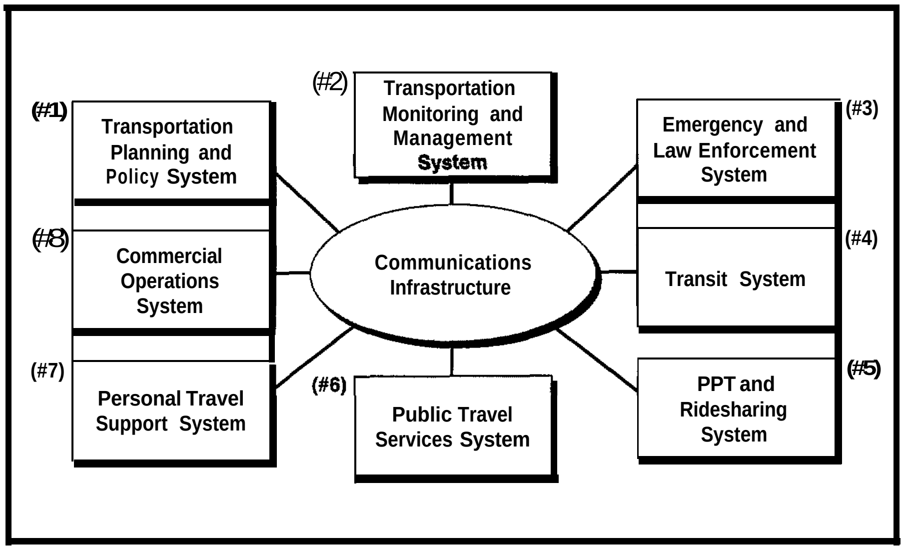


Figure 6. The Westinghouse Team ITS architecture features a set of eight systems connected together by a largely existing communications infrastructure.

System #1 -Transportation Planning and Policy System. This system is an administrative policy setting body with data collection, analysis, and dissemination capabilities. It analyzes the required data, and sets all travel demand management policies and thresholds for traveler alerts regarding environmental and travel conditions. It also issues smart cards to travelers.

System #2 -Transportation Monitoring and Management System. The traditional traffic surveillance and control functions are implemented in this system. All Traffic Management Centers (TMCs) and Traffic Control Centers (TCCs), arterial and freeway surveillance sensors, traffic control devices, and toll facilities are contained here. Tolls may be paid via smart cards or with cash. Travel demand policies are implemented, travel advisories are issued, and link travel times are transmitted for basic in-vehicle route guidance. Adaptive real-time traffic control and incident detection are major functions of this system.

System #3 -Emergency and Law Enforcement System. This system is centered about an Emergency Management Coordination and Administration Center (EMCAC), which receives incident notifications from 9 11 Centers, Mayday transmissions from the traveling public, and high bandwidth traffic surveillance/incident data from the TMCs/TCCs. The EMCAC also informs the Transportation Monitoring and Management System of the nature and extent of all incidents, which in turn informs the traveling public via traveler advisories. It coordinates the response to an incident, notifying the appropriate medical, fire, police, towing, and specialized emergency (such as HAZMAT) dispatch centers. These centers provide dispatch services for their respective vehicles, including centralized route guidance. Vehicles provide their own location information. Emergency signal preemption is provided via RF from the emergency vehicle to intersection signals. The EMCAC can also request a "green wave" from the TMC.

System #4-Transit System. The Transit System provides all public highway borne mass transit capabilities, and may interface with most other forms of public and private transportation, including light and heavy rail, air, sea, commercial carriers, personalized public transit, and ride sharing. Information is disseminated to the public via direct phone contact at the Transit Administration Center (TAC), an extensive shared or wholly owned kiosk network, in-vehicle signage for transit vehicles, and transit stop signage. ADA adherence is specifically called out. Many Park 'n Ride lots are coordinated with transit service in this system. The TAC and its remote/slave centers also provide all public mass transit dispatch services, route scheduling and planning, real-time route guidance and schedule maintenance, and administrative and maintenance functions. Enroute transit vehicles provide their own location data. Signal preemption is available if desired. Security is provided at all points with public interaction. Fares may be paid with smart cards or cash. Express service is easily implemented.

System #5 -Personalized Public Transit (PPT) and Ride Sharing (RS) System. The PPT & RS Administration and Operations Centers are the heart of the fifth system. These centers provide extensive customer interfaces, responding to requests via the transit and public service kiosk networks, personal computers, personal digital assistants, voice line and cellular phones, and a Travel Service Center. The centers provide all scheduling and ride-matching services, dispatching, and financial accounting. They interface with the EMCAC and the TMC for incident and traffic data. Centralized route guidance is provided if desired. Participating vehicles (fleet or private) provide their locations for route guidance. Any given center may be an existing taxi service, a new paratransit service, or devoted to ride sharing. As with the Transit System, security is provided at all public interfaces, and fares may be paid with smart cards or cash.

System #6-Public Travel Services System. System number six provides pre-trip and enroute planning services for all travelers, as well as an electronic "yellow pages" service. The Travel Service Center (TSC) gathers data from a variety of sources, including other travel mode providers, restaurants, special event sponsors, weather bureaus, and map providers. The TSC interfaces with travelers via a kiosk network, in-vehicle devices, desktop computers, personal digital assistants, and line and cellular phones. Parking facilities are also included in this system. The TSC provides premium centralized route guidance and/or high accuracy link times for those travelers who wish to purchase the service. It will make reservations upon request, and provides transit, PPT and RS customer interfaces. Direct interfaces with Systems #l, 2,4, and 5 above are also maintained, so that current data and advisories can be provided to travelers.

System #7 -Personal Travel Support System. This system contains all private in-vehicle ITS equipment, all ITS personal desktop computer and personal digital assistant capabilities, and all ITS smart cards. Vehicle equipment consists of collision avoidance sensors and controls, and traveler information hardware and software provided at various levels of service. Vehicles can provide their own route guidance with link times from the TMC or the TSC, or directly pick up route guidance from the TSC. The option chosen depends on the amount paid and quality of guidance desired. The devices listed above can acquire and maintain direct interfaces with Systems #2, 3, and 6. Communications are maintained via line and cellular phones, RF links, and storage media such as PCMCIA cards, floppy disks, and CD ROMs.

System #8 -Commercial Operations System. The eighth system defined by the Westinghouse Team contains all commercial fleet operations. This includes the fleet administration centers, fleet operations centers, roadside inspection facilities, all commercial vehicles (CV), and state CV administration centers. This system maintains interfaces with all other modes of freight shipment. The fleet operations centers provide scheduling, dispatch and route guidance services. Vehicles provide their own location data. All credential clearance processing is automated. Roadside inspections can be done on the fly.

INITIAL COST ESTIMATES FOR AN URBAN DEPLOYMENT

Preliminary cost estimates for the deployment of our ITS architecture in a typical urban scenario (similar to Detroit) are shown in figure 7 by user, and in figure 8 by system. The total cost is about $1.7 billion. These are the present value amounts for all capital, operations, and maintenance costs over a twenty year period, with additional operations and maintenance costs extending out another 15 years. The most striking aspect of the cost is that private vehicle and household users will pay for almost 75% of the investment in ITS. Although the total cost is large, the average cost per vehicle or household user is less than $300. Clearly, this will be a consumer driven process. Note that government expenses are less than 10% of the total, which implies minimal financial risk to the government sectors. Furthermore, government operations and maintenance costs are less than 25% of the overall government cost.

EVOLUTIONARY DEPLOYMENT Strategy

The deployment of our architecture in various localities and over time is low risk and straightforward due to a variety of features. First, the eight systems are organized along the lines of existing organizations. The TMCs/TCCs have responsibilities which parallel those of today, as does the Transit System. Newer ITS concepts, such as the Transportation Planning and Policy System and the EMCAC, are explicitly defined for ease of implementation, and can be piggy-backed onto existing systems.

Second, extensive use is made of existing infrastructure. The communications network, the Transportation Management and Monitoring System, and the Transit System are all prime examples of this. This reduces the initial outlay required, while maintaining high benefit levels

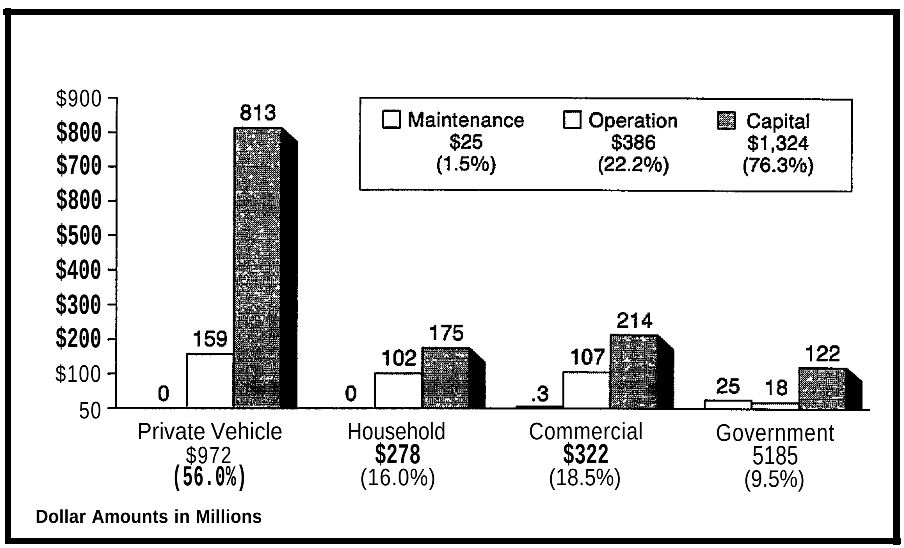


Figure 7. The distribution of costs, by user and type, indicate low government spending, with the consumer bearing the greatest portion of the expense.

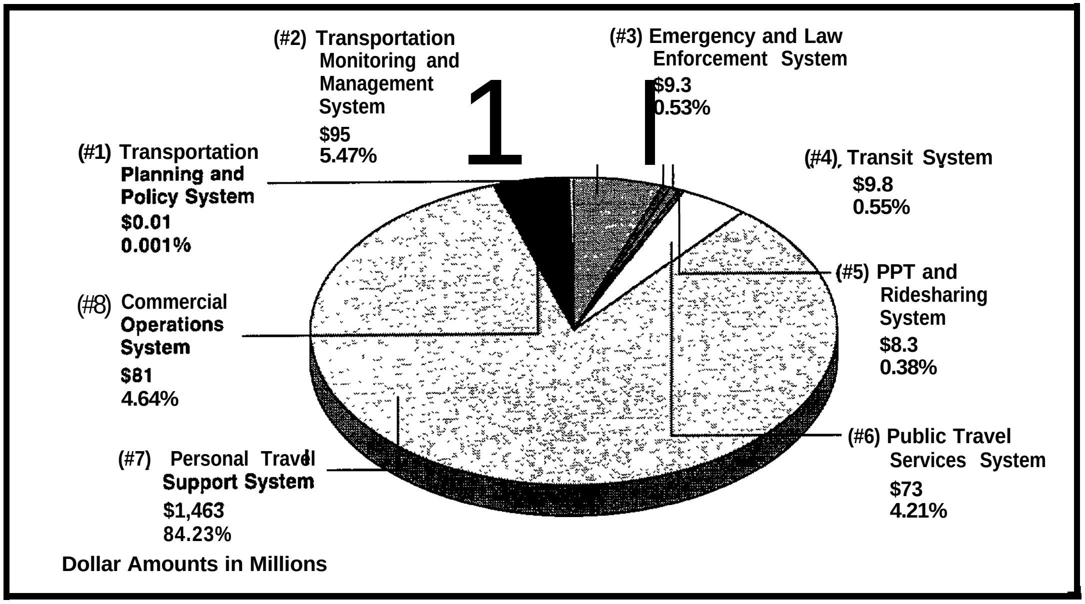


Figure 8. The Personal Travel Support System constitutes more than 80% of the total ITS cost of $1.7 billion, as shown in this breakdown of cost by system.

at an early stage of deployment. The architecture was also designed to minimize infrastructure operations and maintenance costs. For example, we do not require an extensive beacon system to achieve high traffic control performance, although we will accommodate one. This lessens the burden on government, and should substantially enhance deployment flexibility.

Third, the systems are defined in a highly modular fashion. For example, the Personal Travel Support System offers consumers a choice of three levels of in-vehicle and personal computing equipment, and a choice of service providers. This ensures that deployment can be tailored to the wishes of those who pay for it. It also gives them low cost, high benefit options that will encourage the process. This modular design also encourages public/private partnerships. For example, the distribution of information to travelers can be provided by the government or a private service provider, or both, with financial arrangements suited to the individual locality involved. The Traffic Management and Monitoring System and the Public Travel Services System were explicitly designed with subsystems which encourage this cooperation.

Fourth, the architecture is designed to support any reasonable local policy. We have deployed our architecture in a typical urban scenario to take full advantage of its power to bring people to transit, a philosophy we strongly support. However, the architecture will also support different demand management policies, which may emphasize the independence of the individual traveler. The built-in flexibility of the architecture will further ensure its widespread deployment.

Finally, the architecture provides the opportunity to establish a wide variety of standards, which support nationwide seamless operations. This said, it must also be observed that we have maintained options when desirable, to avoid locking out competition and advancing technology. An example of this is our approach to route guidance, which allows both centralized infrastructure-based techniques and decentralized vehicle-based techniques. To deal with the nationwide compatibility issue, standards should specify that whenever a service (such as centralized route guidance) is offered, it is offered in a compatible form. Thus, the architecture offers enough options to encourage service providers, and to enable widespread deployment.

INITIAL PERFORMANCE AND BENEFITS ANALYSIS

Substantial performance enhancements were achieved with the Westinghouse Team urban deployment. The improvements represent the performance change from a Westinghouse non-ITS typical urban scenario to a Westinghouse ITS deployment in that same scenario, over a 35 year period. The ITS deployment is the same as that costed above. A summary of the improvements follows, and is shown in figure 9.

The number of trips per person is up 7%, representing increased traveler mobility and induced demand. This is due to better trip planning and better access to transit. (This does not include the effects of telecommuting, which might reverse this trend.) At the same time, the distribution of vehicle occupancy changed dramatically. Single occupancy vehicles were down 26%. High occupancy vehicles increased by 36%. Transit usage increased by 33%. This is due to congestion pricing via electronic tolls and better access to transit operations.

The number of vehicle miles traveled decreased by 13%, due to higher vehicle occupancy and better trip planning. In addition, the average trip time is down 5%, a decrease achieved in spite of the basically uncongested baseline urban scenario. Furthermore, the total delay time caused by incidents is down 43%, due to fewer incidents and faster response times. As a result of all of these factors, fuel usage and emissions decreased by 14%. Finally, fatalities decreased by 29% and crashes decreased by 33%, due to fewer vehicle miles traveled and increased vehicle safety.

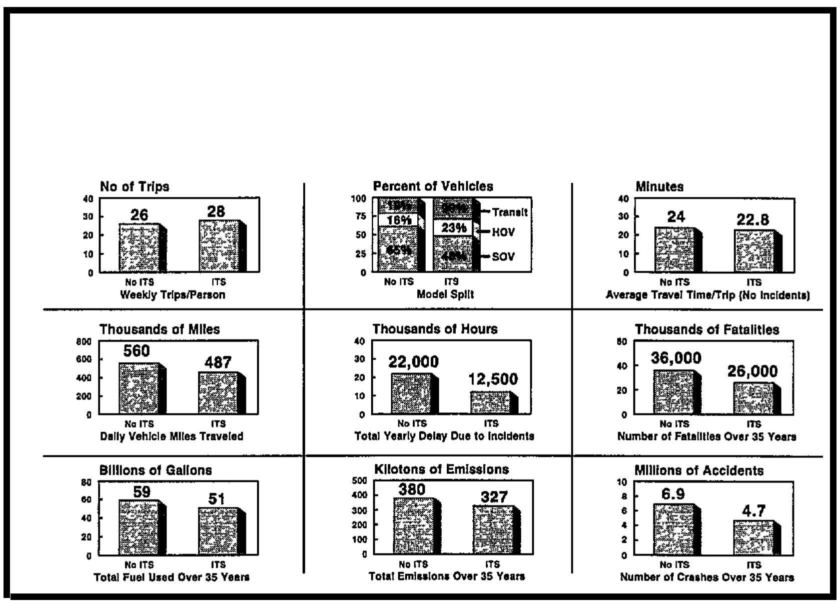


Figure 9. Benefits are substantial. The savings in crashes alone is eight times the cost of deploying ITS!

CONSUMERS

HUGHES

The basic ITS equipment in the vehicle is the tag that communicates with the Traffic Management Center (TMC) via beacons at key locations along the road where a change in route can be made. The information includes advisories for routing around congestion ahead, road conditions, roadside signs, and local business yellow pages. This same device implements electronic collection of toll and parking fees, and is used to pay for other services such as lunch at a drive-through. Early versions of the tag are already in use for paying tolls, and is anticipated to be standard equipment on new vehicles within the next 10 years.

The virtual beacon implementation of this traffic information system requires the vehicle to have a cellular telephone, but extends coverage to any location along the road. This capability is provided by the addition of a GPS receiver which enables the vehicle to know its location. The GPS is already in use for accurate location of vehicles, ships, and planes.

The cellular phone provides the MAYDAY function. The vehicle can initiate the MAYDAY call automatically, for example in response to the air bag inflating. A GPS receiver provides vehicle location to be automatically transmitted to the local emergency service. The cellular phone itself will be standard equipment on new vehicles, in a low cost version solely for the MAYDAY function. Cellular phone coverage in rural areas are based upon satellite systems and require a more expensive version of the cellular phone.

More powerful ITS equipment for the vehicle, the PC-like Route Guidance Computer, calculates the best route for the driver to follow to a destination, and then guides the driver over this route. The guiding may be done with graphics on the computer screen or on a “head-up” display on the windshield, or by voice commands. The destination might be an address or the name of a business listed in the computer’s database. Real-time traffic information is broadcast by the TMC and used by this computer to re-route the vehicle around congestion. The first commercial Route Guidance Computer has just been put on the U.S. market.

Interactive TV is used to do pre-trip planning in the home, at the office, and at kiosks placed in hotels, bus stations and other public areas. Service providers provide the traveler with the best route, considering real-time and anticipated traffic conditions, and including all available modes of travel, (private vehicle, transit, etc.) to take at the time. A Personal Communications Device (PCD) can be “docked” in the kiosk or Interactive TV receiver to store the selected trip plan and then to provide guidance to the traveler on his multi-mode trip.

The Transit Agency provides a real-time display of the current location of all buses at the bus stops. Waiting passengers can watch the progress of their bus and can determine the best choice of alternate transit routing.

Collision warning is provided by radar equipment which is able to detect potential collision with vehicles or other obstacles either in front or alongside the vehicle and warn the driver in time for him to avoid a collision. A first collision warning system is in use on Greyhound buses. Collision avoidance systems will follow, providing the capability for the vehicle to maneuver and avoid a hazard.

Eventually these safety systems may become the basis for an Automated Highway System in which the driver would be able to enter a specialized highway lane and leave the driving to the System. A demonstration of such a system is planned within the next several years.

<u>The benefits of the Hughes Team Architecture are:</u>

1. Mobility is greater as a result of traffic advisories being transmitted to the vehicle at the right time and at the right place for the driver to avoid being caught in congestion ahead. Route Guidance assists a driver in reaching the destination without getting lost and without getting caught in congestion; since the route selection is done in the vehicle the driver can use this system nationwide.

2. Accidents decrease because the traffic advisories reduce rear-end collisions and accidents due to road conditions and poor visibility. In-vehicle sign displays reduce the distraction of trying to read signs at night. Route Guidance eliminates the distractions of trying to find one’s way in an unfamiliar area. Collision Warning, and subsequently, Collision Avoidance are specifically provided to reduce accidents.

3. Greater convenience is a result of “open road” electronic toll collection which permits drivers to drive a toll road as though they

were driving a freeway. Local yellow page information transmitted to the vehicle informs the driver of businesses at the next freeway off ramp, and provide real-time information such as room vacancy. Similarly, the Route Guidance Computer provides an area-wide yellow pages database.

4. Cost Savings result from accident reduction because of reduced vehicle repairs and insurance, plus reduction of time spent in congestion.

See Product and Services Providers for Package availability and Preliminary Cost, page 101.

STAKEHOLDER-SPECIFIC INTERESTS

Level of Anonvmity: By defining route selection/guidance to be done in the vehicle, the concern of someone being able to track a user is eliminated. The tag/beacon and the virtual beacon communication of traffic advisories does not identify either driver or vehicle identification. The toll collection application can be implemented with a "pre-paid" card approach which does not disclose who the toll payer is.

Level of Voluntarv or Mandatorv Participation: The use of the ITS equipment described above is all voluntary.

Level of Users Control Over Their Mobilitv: By defining route selection/guidance to be done in the vehicle, the driver retains control over his mobility. The problem of availability of route selection services nation-wide or even jurisdiction-to-jurisdiction is avoided. The Route Guidance Computer does need to have a database for the area being driven, but market forces are working to make databases readily available for any area of the country. The driver's response to advisories transmitted into the vehicle is voluntary.

LORAL

Consumers will be the beneficiaries of many of the ITS User Services. The Loral Team believes these services will be deployed as follows:

In the five year timeframe, wireless 2-way data communications will be possible via cellular data services for 90% of the population. ***Communications privacy*** will be assured by use of inexpensive but effective encryption built into data and voice equipment. Personal information will only be stored at ISPs and then only when there is a clear benefit to the consumer. ***Dynamic route selection and guidance*** will primarily be limited to autonomous in-vehicle equipment. A few advanced systems will receive routing and multimodal trip planning from ISPs. ***Roadside electronic transactions*** will be based on positive balance toll-ID tags used on toll roads.

In the ***ten year*** timeframe, ***2-way data communications*** will be provided to 95% of the population via cellular data services with satellite data services to seamlessly augment the terrestrial cellular system, resulting in 100% geographic coverage. ***Dynamic route selection*** for in-vehicle or portable equipment will be available from ISPs. For ***roadside electronic transactions,*** toll-ID tags will begin to converge with other payment technologies (early systems were positive balance devices for single systems only) to allow broader regional and modal use.

In the twenty year timeframe, for ***dynamic*** **route** ***selection the*** best trips and routes are now regularly supplied and updated dynamically to vehicles from ISPs. Non-driving travelers are also fully supported with ***these*** services via wireless devices. For ***roadside electronic trunsuctions,*** toll-id tags converge with other payment technologies to support non-ITS specific proximity payment systems. Positive cash balances are no longer kept on the "tags", which now solely provide ID access to Electronic Funds Transfer services. In the ***twenty year*** (and beyond) timeframe, vehicle-to-vehicle data communications will emerge to support advanced vehicle control (platooning) and Automated Highway System services.

PROVIDES LOW/NO COST TRAVELER INFORMATION SERVICES

All travelers will benefit from better regional travel information broadcast by AM/FM/Cable operators as they begin to use travel information from local TMCs and ISPs via ITS media interfaces. Also, extensive Highway Advisory Radio (HAR) can be publicly deployed for local advisory information based on real-time TMC and ISP probe surveillance.

Public transportation carriers will be able to offer schedule and schedule-variance information to ISPs through a standard interface, so that this information can be used by travelers to get additional routing options. This interface will mutually benefit travelers, ISPs and the public transportation agencies at no or low marginal cost to the travelers.

PROVIDES CHOICES FOR THE TRAVELER SELECTION OF TRIP MODE

Modal choice is facilitated with the real-time information provided on all modes of transportation. ISPs provide trip planning services that can be generic or personalized, providing plans and ticketing across all transportation modes. Users can choose among modes based on cost, convenience, and other needs.

PROVIDES CHOICES FOR THE TRAVELER SELECTION OF EQUIPMENT

Many equipment options are supported for both individual and commercial users. These implementations provide varying levels of performance with associated levels of cost to the user. For example, in providing route selection services the Architecture accommodates three distinct operating modes:

1. Traveler-based route selection

Route selection processing equipment and the navigable database that route selection is based on are located with the traveler (either in their vehicle or in their portable computer). Routes are chosen totally autonomously by the traveler. This approach is not dependent on any infrastructure deployment, allowing use immediately in rural as well as in urban environments.

2. Traveler-based route selection receiving broadcasts of link/queue-times prepared by ISPs

In this mode, traveler-based route selection is augmented by data from the infrastructure about current and predicted road segment travel times. Using this data, the traveler equipment will be able to compute better routes than mode 1 because they will be based on actual current and predicted conditions. This mode of operation requires a communication link to the infrastructure in addition to the equipment needed in mode 1.

3. Traveler based route guidance coupled to infrastructure based route selection

Routes are chosen by the traveler from choices offered by the ISP. In this mode, the traveler equipment is simplified because it no longer requires a navigable map database nor the computational power to perform the route selection since the multimodal trips and routes are computed in the infrastructure (at the ISP). A two-way communications link with the infrastructure is required so that the traveler can send a trip request to the ISP and receive route candidates in return.

PROVIDES TRAVELER PRIVACY CHOICE

The route selection choices above offer a range of options with respect to privacy for the traveler. The traveler can select routes totally independently of any infrastructure-based entity, or he/she can choose a higher level of personalized service from an ISP. This ISP service requires the ISP to know the traveler's progress towards the destination and involves sending personalized data messages to the traveler's equipment. ISPs can choose to offer "cash" based accounts for travelers that desire to be completely anonymous.

The Loral architecture specifies that personal or confidential data stored in the infrastructure (to provide a selected user service) is only held at ISPs, not at TMCs. By limiting personal or confidential information to the records of private entities, this information is not publicly available by federal or state Freedom of Information Act (FOIA) inquiries as it would be if it were held in public agency records.

The Loral architecture specifies state-of-the-art processes for message exchange using dual-key encryption and authentication methods. This assures that personal or confidential information is not easily available by unauthorized access or eavesdropping, and that the architecture will be extremely resistant to theft of services by "spoofing" (pretending to be someone else).

ROCKWELL

CONSUMERS ULTIMATE BENEFICIARY

In the architecture proposed by the Rockwell Team, consumers are the ultimate beneficiary of the ITS services. They receive improved travel options, increased mobility, improved safety, and enhanced security. They have the convenience of being able to obtain different types of data when they need it, using the same device. The consumer is afforded increased flexibility to use and pay for what they need when they need it through a variety of vendors and different services. Market driven forces provide access to services by all economic groups at reasonable costs commensurate with derived benefits. Finally, the user is assured of autonomy and control over his/her own mobility and uncompromised privacy and anonymity, The Team has performed extensive market assessments and has conducted focus groups to determine the expected market for ITS services. These assessments showed that consumers are not an easy sell. There is a lot of competition for disposable income. Willingness and ability to pay for expensive services is limited. Consumers in general tend to shy away from complex/unfamiliar technologies. Niche markets, however, do exist with specific needs. Personal security is a major concern and is an area where individuals are willing to pay. Finally, the market predictions are very uncertain because, up to now, consumers have only been exposed to the limited benefits of ITS services. In order to get new services started the services need to be incrementally packaged to provide a wide variety of benefits to consumers. Those which are cost effective and provide real benefits will probably catch on.

MARKET PACKAGES ARE **INCREMENTAL**

The Rockwell Team has proposed consumer oriented market packages in the areas of Advanced Traveler Information Services (ATIS), Advanced Vehicle Safety Systems (AVSS), traveler friendly Transit Services, and services for Commercial Vehicle Operators (CVO). The market packages are designed to allow consumers to select the level of service desired. All market packages provide flexibility in choosing desired services at graduated cost. Additionally, the Rockwell team's open architecture ensures that a host of product vendors and service suppliers will be available for the consumer to choose from. This fosters competition and hastens the reduction in user prices.

Advanced Traveler Information Services are one of the key elements which consumers have requested from ITS. The architecture provides a broadcast based market package which is intended to be offered by the infrastructure at no cost. This service provides real-time advisories and transit schedule deviations, however it may not provide information sufficiently specific for a frequent traveler. For a driver or traveler who desires to optimize a trip, a set of market packages are available which provide the information necessary to plot an optimum route.

With the infrastructure based route guidance market package, a traveler can inform the service provider of his/her location through a portable device, or the infrastructure may determine his/her location through the communication system. The infrastructure can then provide a route plan. Included in this service are ride matching, ride sharing, and the options of taking public transit, or paratransit. Penetration for this market package is expected to be up to 7% of the vehicles in the 20 year time-frame.

The in-vehicle ATIS route guidance package, includes a 2-way cell-based digital communication device, a GIS, a GPS device, and a user interface. This equipment package is estimated to cost about $1400 when first offered, with prices coming down to about $600 over several years. In this market package, the infrastructure only provides the user with up-to-date congestion and transit schedules, and the in-vehicle equipment plans the. route and provides step-by-step guidance along the route. The 2-way cell-based communication device is based on current CDPD technology and assumes nationwide coverage, seamless service operation, nationwide roaming, and automated/consolidated billing. This digital medium affords very efficient use of the spectrum by using existing infrastructures, spectrum allocations, antenna towers, and occupying the air waves for only the time required to transmit a short digital message. This time is much shorter than that required for an individual to make a verbal request and get an adequate response, and therefore, much more economical. Because of the costs of in-vehicle equipment, the market penetration of the service over 20 years is expected to reach only 3% of the vehicles (less than the least expensive infrastructure route plan) and 7% of the traveling public.

Additional in-vehicle features include in-vehicle signing, a Mayday facility included with the 2-way communication device, on-board safety devices, improved visibility, and additional safety and convenience devices for the vehicle. Standards for these services will evolve as functionality develops. Expected market penetration, although small, is still quite significant by year 20, with emphasis on in-vehicle safety systems. Total in-vehicle equipment for these advanced features, once they become technically viable, may range from $150 for simple safety and cruise control devices, to $1100 for advanced pre-collision detection and visibility improvement equipment.

A short range communication device facilitates automated toll payment using either a value or credit card. The in-vehicle device can also be used for equipped parking structures.

No discussion of consumer services would be complete without addressing privacy and anonymity. Information between a consumer and his service provider is protected through encryption requirements on the communication links and security access requirements on the databases. Use of a value card allows a consumer to be totally anonymous. No vehicle ID's are required and vehicle tracking is only done with the driver's permission. Participation as a vehicle probe is voluntary.

WESTINGHOUSE

Deployment-Oriented Specifics: Consumers are primarily concerned with System #7 (Personal Travel Support System - see figure 10), which is designed to make consumer participation simple. They will purchase the equipment in this system, which is highly modularized and offers various levels of service. For in-vehicle equipment, we estimate the price of the basic option at $175, the standard option at $675, and the premium option at $1000. The advanced system includes all of the vehicle sensors and control interfaces, and has an estimated price of $300. See figure 11 for a more detailed presentation of the ITS vehicle equipment. Consumers also have the option of purchasing a service from the Travel Service Center (TSC) in System #6 (Public Travel Support System) at an estimated $lO/month, in which case some of the above equipment may be provided at a much lower cost by the TSC. Because of the large number of consumers involved, this is the most expensive system more than 80% of the total ITS cost. The benefits are numerous and substantial, as shown in figure 9 on page 5 1.

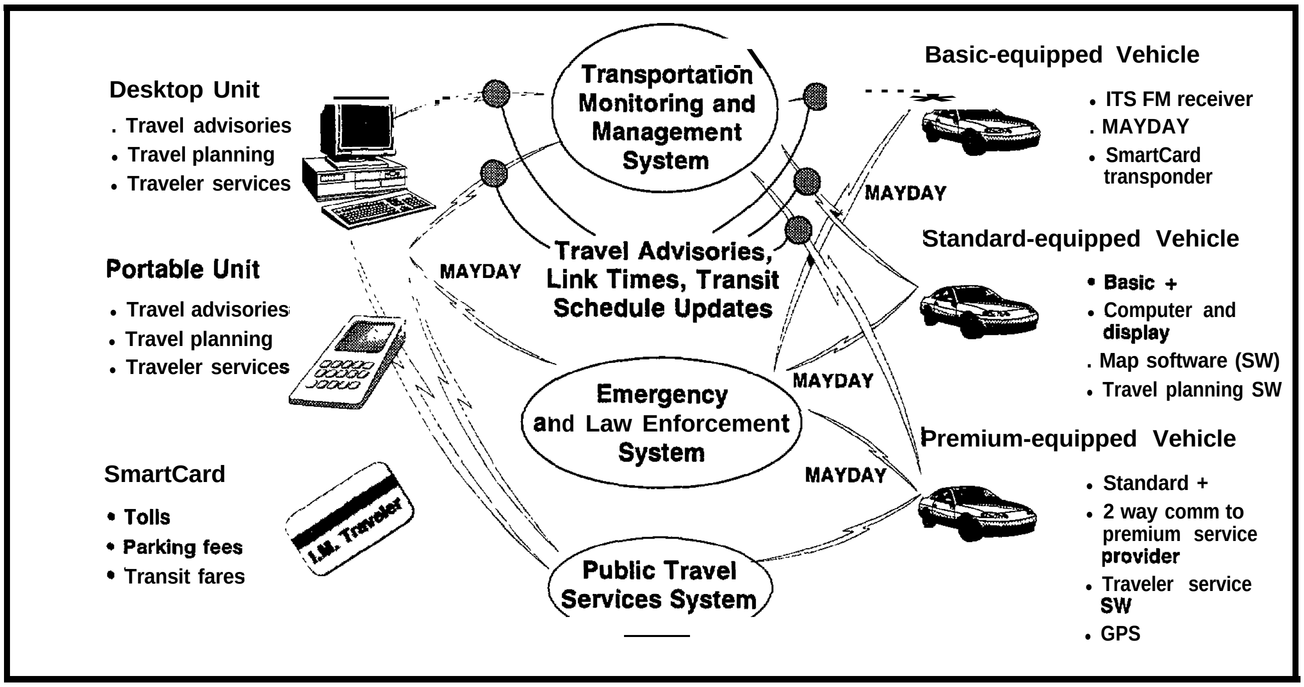


Figure 10. The Personal Travel Support System provides consumers with a wide variety of choices.

Privacy and autonomy: Ou approach to the architecture is expressly designed to provide absolute preservation of privacy to those who demand it. We do permit reasoned access to non-prejudicial information in return for a higher level of service for those willing to participate in the transportation system.

Access to data is a policy, not architecture issue, but Westinghouse is dedicated to the premise that the architecture will not reauire divulgence

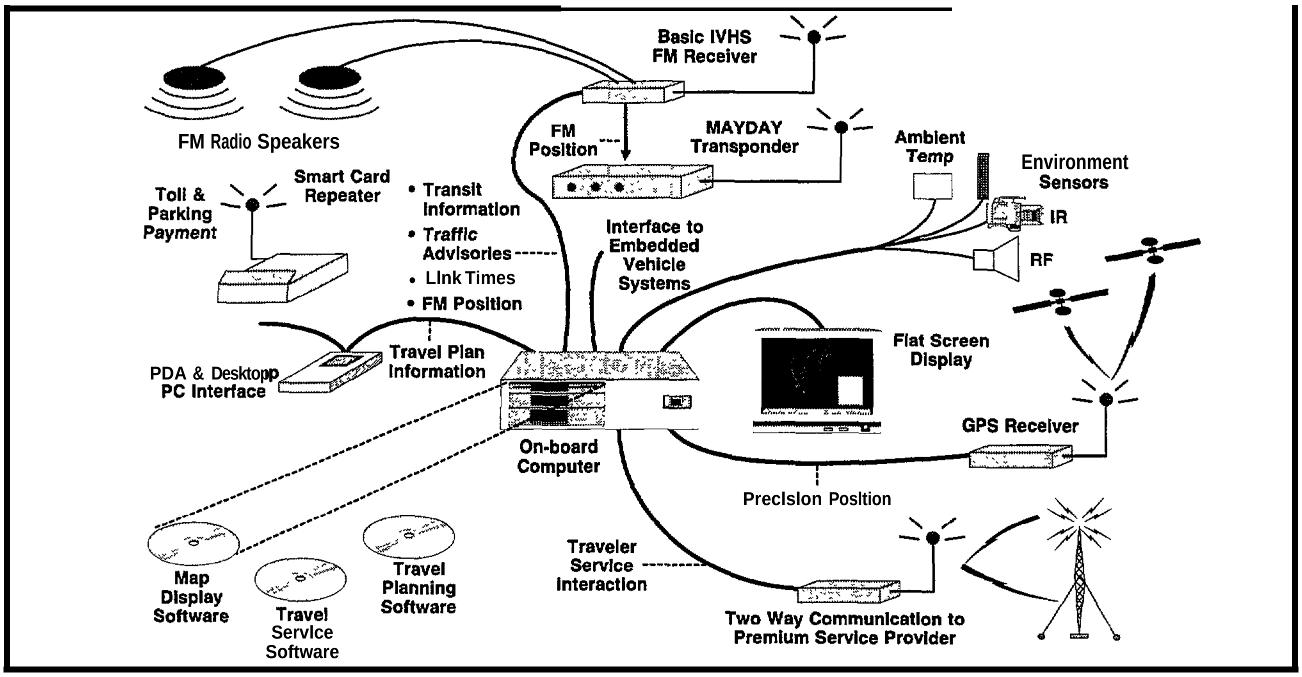


Figure 11. The ITS in-vehicle equipment provides collision avoidance and traveler information.

of information about the whereabouts or actions of any person, within the operating parameters of the system. For example, a smart card user must reveal his/her card ID to the reader, but nobody except the financial institution needs to know who the individual was, or where and when they made the transaction. In fact, we also accommodate more anonymous methods (such as coin collection) to give the users absolute control over their level of participation without jeopardizing their mobility. The level of user participation is again a policy issue, not an architectural issue. The architecture will accommodate any reasonable policy regarding required levels of user participation.

The consumer has complete control over his/her own mobility, although policy makers can restrict this via congestion pricing if desired. There is no provision for completely coupled centralized route guidance, wherein every driver is told precisely which route to take by a central control center. Westinghouse does not believe this is a practical'option in this society, and its inclusion would add significant new infrastructure.

Consumer Equity As described above under Deployment - Oriented Specifics, consumers have a large number of options regarding the services they choose to purchase. The architecture is structured so that consumers pay directly for the level of service received. Thus, benefits accrue in proportion to the amount invested. However, very small capital investments yield a large payback, so that participation should be high. Consumer investment is protected by the establishment of standards to ensure nationwide compatibility wherever a service is offered, and by providing options which are largely independent of infrastructure. The equipment shown in figure 11 is also very reliable, similar to your FM radio. This further enhances any investment.

TRANSPORTATION INFRASTRUCTURE PROVIDERS

HUGHES

The capability to manage traffic is enhanced as a result of new techniques for earlier prediction of traffic congestion, and of new tools to manage the traffic congestion. Both result from a high level of interaction between vehicles and the Traffic Management Center (TMC). Communication between the vehicles and the TMC is accomplished via tag/beacon at key locations along the road and via the virtual beacon at any location commanded by the TMC.

As the vehicles pass a beacon they provide data collected since passing the previous beacon. Travel time ("probe" data) and speed variation data, when combined with static sensor data, are indicative of traffic conditions; new traffic congestion prediction algorithms based on this data offer the promise of significantly more accurate results. The vehicle's traction control system provides an indicator of slippery road surface. Engine parameters indicative of vehicle pollution levels can be measured. Driver visibility can also be measured. The Hughes Team has named this data the "super-probe" message.

In return, the TMC delivers real-time traffic advisories for display in the passing vehicles, at the right beacon location and at the right time to enable the vehicles to take evasive action. Advisories warn of incidents and unusual congestion, slippery road surface, poor visibility, and reports of debris on the road ahead of the vehicle and provide re-routing instructions. In addition, the beacons deliver road-side sign messages and local yellow pages information to the vehicle (see the Consumer Section). The TMC also maintains an Origin/Destination database by writing on-ramp ID's into the tags as vehicles enter a freeway, and comparing these ID's to exit ramp ID's as they leave the freeway.

The Hughes Team Architecture applies these concepts to freeway, toll road, arterial and corridor traffic management systems. The corridor systems involve cooperative operation of multiple jurisdictions. The arterial systems make further use of the tag/beacon communications to provide turn and platoon data to adaptive closed loop signal systems.

The inducement for vehicle owners to install the equipment to provide probe and superprobe data is the ability to receive the advisories, in-vehicle signs and local yellow page information, to automatically pay tolls and, for commercial trucks, to by-pass weigh stations. Transit systems install the equipment to provide bus tracking. A relatively small penetration (2-5%) of equipped vehicles are enough to provide sufficient information. Probe, super-probe, and advisory functions preserve total privacy for driver and vehicle owner.

Another tool for managing traffic is the route guidance vehicle which the Hughes Team Architecture defines to be autonomous, doing its own route selection. However, the TMC broadcasts predicted travel times for congested road links, which the vehicle's computer uses to select its best route. This gives the TMC the capability to implement congestion mitigation strategies, such as distributing traffic being diverted on to a number of alternate routes, and interjurisdictional policies, such as restrictions on the diversion of freeway traffic on to neighborhood streets.

<u>The benefits of the Hughes Team Architecture are:</u>

1. faster, more accurate incident detection provided by probe and superprobe messages;
2. faster and more precise congestion mitigation because beacons are much more closely spaced (for the same investment) than Changeable Message Signs would be;
3. increased safety as a result of advisories reducing the likelihood of rear-end collisions;
4. more accurate ability to plan and optimize the system as a result of having extensive, up-to-date historical Origin/Destination data;
5. increased tax payer support as traffic flows noticeably better even as the Architecture is incrementally implemented.
6. opportunity to reduce costs by sharing beacons with the transit agency.

See Product and Services Providers for Package availability and Preliminary Cost, page 101.

STAKEHOLDER-SPECIFIC INTERESTS

<u>Partnerships</u>: Partnerships between public sector agencies and private sector firms include:

1. marketing of real-time traffic information to pre-trip planning service providers.

2. franchise of the roadside beacons to service providers who sell yellow pages advertising to local businesses for availability via tag/beacon to vehicles at freeway exits;

3. franchise of toll facilities.

Standards/Compatibility: The Hughes Architecture is designed to integrate with existing systems, incrementally improving the performance of the systems as more of the ITS equipment is installed. For example, the beacon can be installed in the same controller cabinets now in the field, using the same power source and the same communications to the TMC. The virtual beacon is even more readily integrated with current systems since it does not require any new infrastructure as it uses the public cellular phone service.

Standards are required for Vehicle-Roadside Communications protocol, technical implementation, and message formats. Real-time traffic information and road database interfaces must be standardized.

The Hughes Team Architecture reduces life cycle costs because all equipment is out of the road, including beacon antennas and static vehicle sensors. The Architecture accommodates road pricing, which would provide long term O&M funding.

New roles will require training of TMC operators in the use of new computerized management tools required to be able to exercise the capabilities of the new TMC.

Implementations of the Hughes Team Architecture are very reliable systems as a result of the distributed architecture and the ability to dynamically reconfigure the system. System reconfiguration capabilities include the assignment of virtual beacons to fill in for failed fixed beacons, the switching of beacons to another Area Processor, the Area Processor assumption of the basic functions of a failed TMC, and switching to a backup TMC.

LORAL

The Loral architecture envisions that transportation infrastructure providers will maintain their traditional roles in traffic and incident management. The architecture will substantially enhance their ability to perform these functions in the first twenty years of deployment:

In the five yeartimeframe, advanced adaptive and coordinated traffic light control systems will be the norm for upgrades of urban infrastructure. A few regions will begin to experiment with centrally provided signal priority for public safety and transit vehicles, based on ***"probe information"*** these vehicles supply describing their position and route. Enhanced ridesharing will be an early advanced transit option.

At ten ***years,*** incident detection will be faster and more accurate. The improvements will come from automated algorithms and the use of probe information from vehicles as a supplement to roadway sensor loop and camera data. The probe information is supplied to the TMCs from the

ISPs, which get it from vehicles to which they supply routing services. The availability of these different types of data will also allow TMCs to collect historical traffic data, to better model and predict roadway demand.

At twenty years, we will see advanced deployments in many areas:

- ***Congestion prediction:*** TMCs will use data from their fixed sensors and vehicle probe information from ISPs in advanced predictive models. These models will allow sophisticated coordinated and anticipatory signal scheduling, providing traffic light scheduling on a progressively more individualized basis.
- ***Demand management: TMCs*** will be able to implement regional demand management policy. The tools will be road usage restrictions by vehicle class or occupancy and transportation pricing using sensors, toll-ID tags and transit fares.
- ***Traffic control:*** Vehicles receiving route guidance from ISPs will experience improved optimization of routing and traffic signal coordination. This is made possible by real-time data exchange between TMCs and ISPs.
- ***Incident management:*** The detect-to-dispatch times will decrease to a few tens of seconds, using vehicle probe information supplemented by roadway sensors. Vehicle probe and MAYDAY transmissions will ensure full rural coverage, and all areas will benefit from the integration of E-9 11, incident management, and emergency fleet management.
- ***Systemplanning:*** Advanced modeling and simulation will be possible using databases distributed across multiple TMCs. These models, working with historical and real-time data, will allow the optimal use of TMC and regional DOT resources.

To achieve this twenty year deployment scenario, the Loral architecture advocates a set of critical, required features, which are discussed below.

SUPPORT LOCAL DEMAND MANAGEMENT POLICIES

Where regional demand management policies are deemed appropriate, the Loral architecture explicitly supports the following:

- Support for all levels of demand management, from basic signal control, to roadway access priority for certain classes of vehicles, to coordinated transportation pricing across all modes.
- Demand prediction capability through the coupling of TMC demand modeling algorithms and ISP supplied route selection information.

These capabilities allow local jurisdictions to take appropriate actions to realize service level, environmental quality, and budgetary goals.

ENCOURAGE EFFECTIVE PARTNERSHIPS

The Loral Architecture provides unique opportunities for public/private and public/public partnerships. These partnerships will improve the quality of services that are provided and lower the costs to the transportation infrastructure providers. Partnerships explicitly supported in the architecture include:

- The use of commercial providers of wireless and wireline communications, freeing the transportation infrastructure providers from deploying and maintaining the communications infrastructure.
- Coordination between TMCs and public agencies to support interjurisdictional cooperation.
- Coordination between TMCs and ISPs to support mutually beneficial exchanges of traffic and routing data.

The Loral Architecture is built on the beliefs that: (1) public sector infrastructure should benefit all users, (2) personalized services can best be provided by the private sector, and (3) wherever possible existing infrastructure should be used to support ITS goals. Based on these tenets, effective partnerships are encouraged by the Loral architecture.

PROMOTE STANDARDS AND PROTECT EXISTING INVESTMENTS

The Loral Architecture clearly defines where standards are needed to insure beneficial market competition among service and product providers. This competition will make infrastructure deployments more affordable. At the same time, the Architecture emphasizes the inclusion of multiple deployment options, recognizing existing and future infrastructure. This ensures that early infrastructure deployers will not see their investments become obsolete.

For example, much current public infrastructure investment exists in the TMC-to-Roadside communications and in TMC and Roadside equipment. We have designed the Roadside and TMC subsystems so that the current infrastructure can continue to be used and integrated with new features provided by the architecture.

AFFORDABLE OPERATIONS & MAINTENANCE

The Loral Architecture emphasizes affordable transportation infrastructure life-cycle costs through the use of existing and future commercial infrastructure providers. For example, the wide area communication infrastructure is operated and maintained by the communications service providers (CSPs). The operation and maintenance costs of the TMC are then focused on the TMC equipment itself and on the Roadside equipment.

In the Loral architecture there are no special TMC or Roadside reliability requirements beyond what is practiced today. This is a part of the architecture's fail-safe design which places new safety-critical systems in the vehicle, rather than in the infrastructure. As a result, the maintenance burdens will depend solely on the complexity of the infrastructure deployment, and not on any new stringent requirements dictated by the architecture.

Avon, NEW PUBLIC AGENCY LIABILITIES

Some of the User Services carry with them new or increased liabilities for the providers of the service. We have taken specific steps in the architecture not to place these new liabilities on the Public Infrastructure Providers. For example, vehicle control in the Collision Avoidance and Automated Highway System (AI-IS) services, is maintained in and between vehicles in the Loral architecture. The infrastructure does not play a significant role. Similarly, Loral proposes that in-vehicle signage services be provided by private ISPs as part of the route guidance function. This allows the private organizations to choose the level of in-vehicle signage service to offer and to manage the associated liability.

ROCKWELL

DOES NOT PRESCRIBE A SYSTEM DESIGN

One major feature of the Rockwell Team architecture is the development of a collection of market packages providing incrementally increasing capabilities to meet a local areas needs. A basic package involves aggregation of congestion data and detection of incidents for distribution to traveler information services. More sophisticated features include interconnecting the area to adjacent areas and the sharing of data and control based on prearranged procedures. Urban areas may take advantage of automated toll, HOV lane management capabilities, reversible lane and electronic signing, emissions measurement, in-vehicle signing, and travel demand management facilities. Although the architecture supports all of these capabilities, it does not dictate how a jurisdiction should manage its own congestion nor does it prescribe a system design.

Division of functional capabilities into separate subsystems provides an opportunity for several cooperative entities, either public or private, to participate. Obvious financial partnerships in which the public sector provides investment for infrastructure instrumentation and emergency response, and the private sector provides information dissemination to travelers and drivers, are encouraged because of the way in which the architecture's subsystems have been defined. By making it easy to distribute real-time data over the land line backbone, new industry starts are facilitated which can enhance ITS services or provide new and inventive solutions to congestion and emissions problems. Multiple players that have the ability to exchange information, improve the reliability of the entire system by introducing new ways to measure and control congestion.

COMMON INTERFACE FOR VEHICLE TO ROADSIDE

From a congestion management point of view, one real advantage of the Rockwell Team architecture to the transportation infrastructure provider, is in the ability to use a standard interface to deal with tolls, demand management, and in-vehicle signing. All of these capabilities would use the same short range vehicle to roadside communication media. The transportation center may assess fees or otherwise control vehicles through local areas using automated facilities. Drivers may pay for services with either a value or credit card based on a standard developed for nationwide compatibility.

The architecture makes available alternatives to single occupancy travel, such as providing real-time transit schedules, ride-matching, and ride-sharing. An emphasis on convenient and efficient utilization of alternate transportation modes is included as an alternative to mandatory congestion control mechanisms.

In addition to the short range communication device, drivers may acquire a 2-way communication capability with an information provider (initially $1420/vehicle) through which they may obtain advisories as well as congestion data. This in-vehicle equipment contains roadway map data, a graphic display, a digital cellular phone/CDPD modem, GPS or DGPS, and a trip planning computer. A broadcast receipt capability is also included for a lower cost. Simulation has shown that with real-time congestion and advisory information, depending on penetration of the service, a user may achieve up to a 50% reduction in travel time for long trips (e.g. 30 min.), and because these equipped users have avoided congested areas, there is an overall system benefit of several percent reduction in travel time. A user may also choose to contribute to the infrastructure instrumentation by being a probe. Due to privacy issues, in the Rockwell Team architecture, participation as a probe is voluntary. The architecture supports the collection and management of cooperative probe information by the traveler information service provider over the wide area cell-based communication infrastructure. Simulation indicates that adequate congestion information can be obtained using only 1% of the vehicles on the roadway. If there is sufficient participation by the public, both in purchasing the equipment and volunteering to be a probe, this wide area probe concept provides the infrastructure with instrumentation over the entire roadway system, as opposed to only those areas equipped with beacons. It also allows the infrastructure to dynamically adjust data collection efforts to problem areas. Methods are suggested for ensuring even drivers who volunteer to be probes of privacy and anonymity. Total air-time costs for a 2% penetration of an Urban area of 3 Million people, amounts to about $3M/year.

PARTICIPATION AS PROBE IS VOLUNTARY

The architecture also facilitates the reduction of congestion between adjacent areas by exchanging vehicle densities and signal timing plans in real-time (once every 30 seconds is recommended). Data loading analysis indicates that a 64 Kbit leased line can accommodate the data rate. It has been shown that coordinated signals reduce delay, stops, and improve traffic flow. Exchange of data is the key to coordination. The development of improved algorithms for effective coordination of control signals is recommended along with development of traffic prediction models to anticipate congestion problems before they occur. Imagery can also be exchanged if a higher bandwidth fixed infrastructure is available. PDDI-II and the emerging ATM and SONET support the necessary compressed video rates.

Total investment by the public into the Transportation Infrastructure over 20 years is anticipated to be from $30M over the next 5 years to $152M over 20 years. Most of this cost is installation of imaging capabilities, roadway sensors, and controls, with about 3% on a limited number of Toll Plazas and 7% in traffic management centers. Operational costs are estimated to be up to $25M/year in 20 years including maintenance of the newly installed equipment, leased line communication charges, and operations costs at the TMC.

WESTINGHOUSE

Deployment-Oriented Specifics: The major systems of interest to the transportation infrastructure providers are Systems #1 and 2 (the Transportation Planning and Policy System - see figure 12, and the Transportation Monitoring and Management System - see figure 13), along with the Communications Infrastructure. These systems utilize existing infrastructure to the greatest extent possible, so that services are low cost and come on line rapidly. For example, video cameras gradually replace loop detectors, at no additional cost. Existing fiber optic cable is assumed in the urban deployment. Intricate new structures are not required. Cost is minimal; ITS enhancements to Systems #1 and 2 consume about 5% of the total ITS cost (see figure 8 on page 50). These enhancements constitute a large part of the additional communications and highway infrastructure (about 8% of the total - largely for express bus flyover merge lanes - see figure 14). In all, additional government costs are less than 10% of the total, which minimizes the risk of building unused infrastructure. As shown in figure 9 on page 51, 13% lower vehicle mileage results in a further reduction of road maintenance costs. The reduction in crashes by 33% will also result in lower costs. Benefits to the taxpayer are substantial, and easily justify the added cost.

Communications Infrastructure: The eight systems described in the overview communicate within and among themselves via a flexible communications network, shown in figure 15. A large part of this infrastructure already exists. The existing switched and dedicated phone network is used for routine fixed point to fixed point communications. Existing twisted pair land lines can provide sensor and traffic device control for the traffic monitoring and management system.

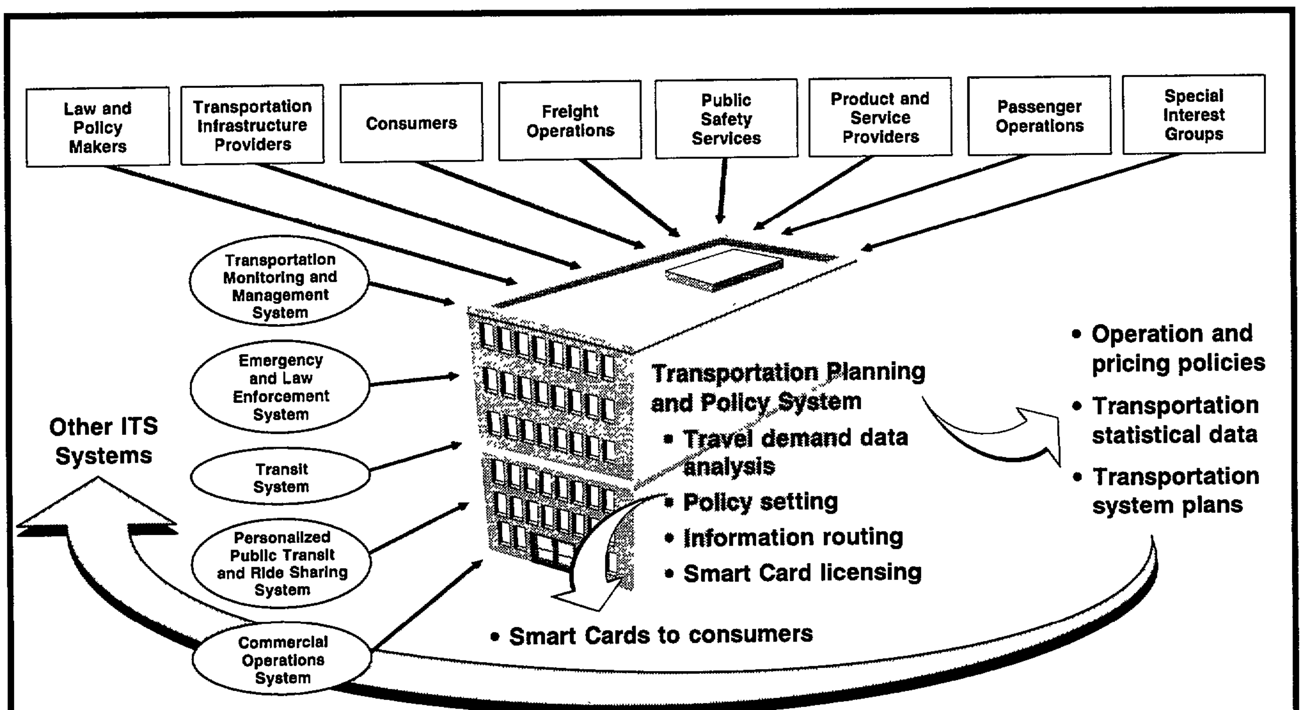


Figure 12. Travel demand management is provided via the Transportation Planning and Policy System (System #1), which will support any reasonable local policy.

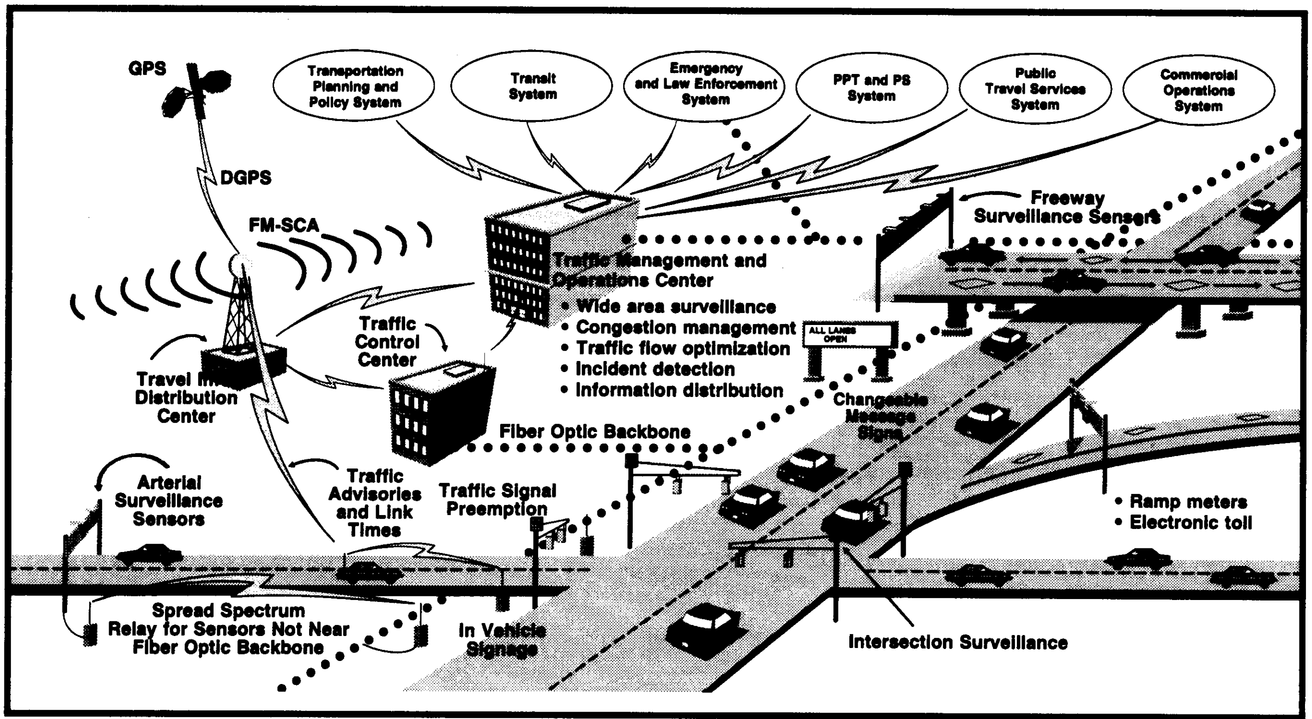


Figure 13. The functions of the Transportation Monitoring and Management System (System #2) are focused on real time adaptive traffic control.

Additional dedicated communications lines may be required in some locations. Typically, fiber optic cable or microwave links are used to provide high volume data and video data from the arterial and freeway sensors back to the TMCs/TCCs, and to relay that data to other centers. Spread spectrum radios may be used to relay sensor data to the fiber optic

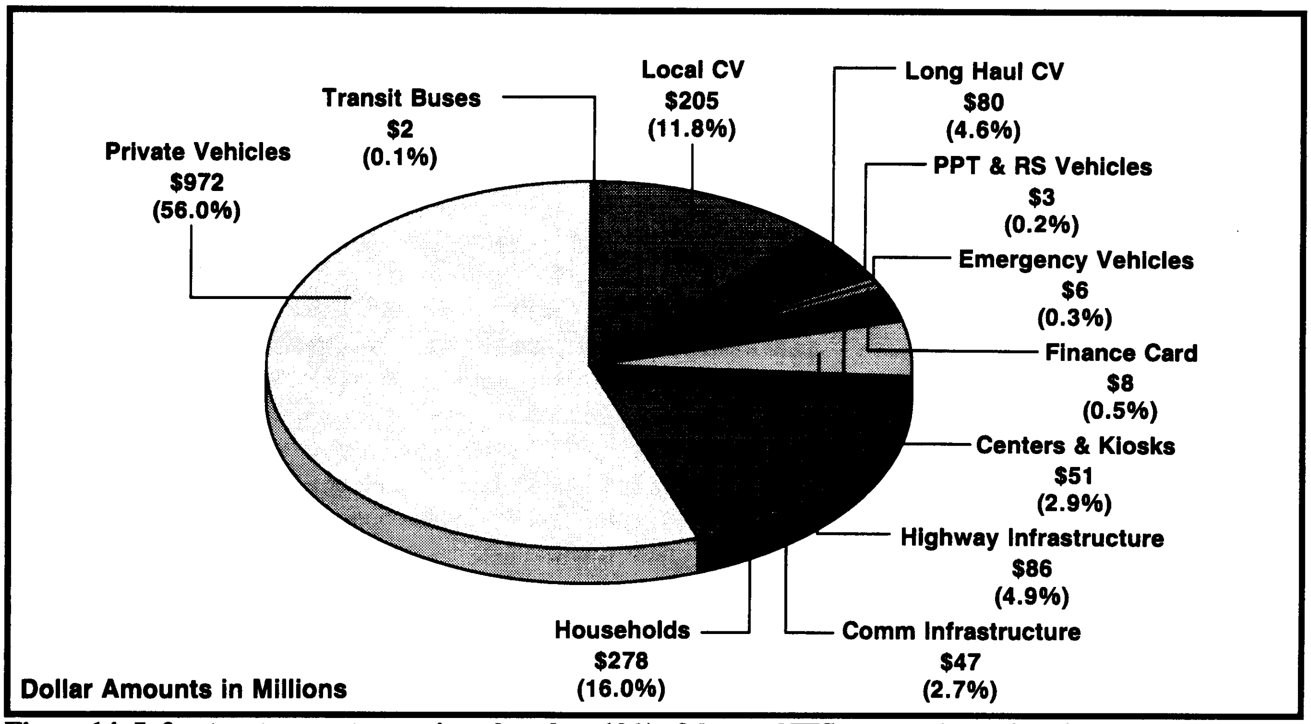


Figure 14. Infrastructure costs constitute less than 10% of the total ITS cost, as shown in this breakdown of cost by types of equipment.

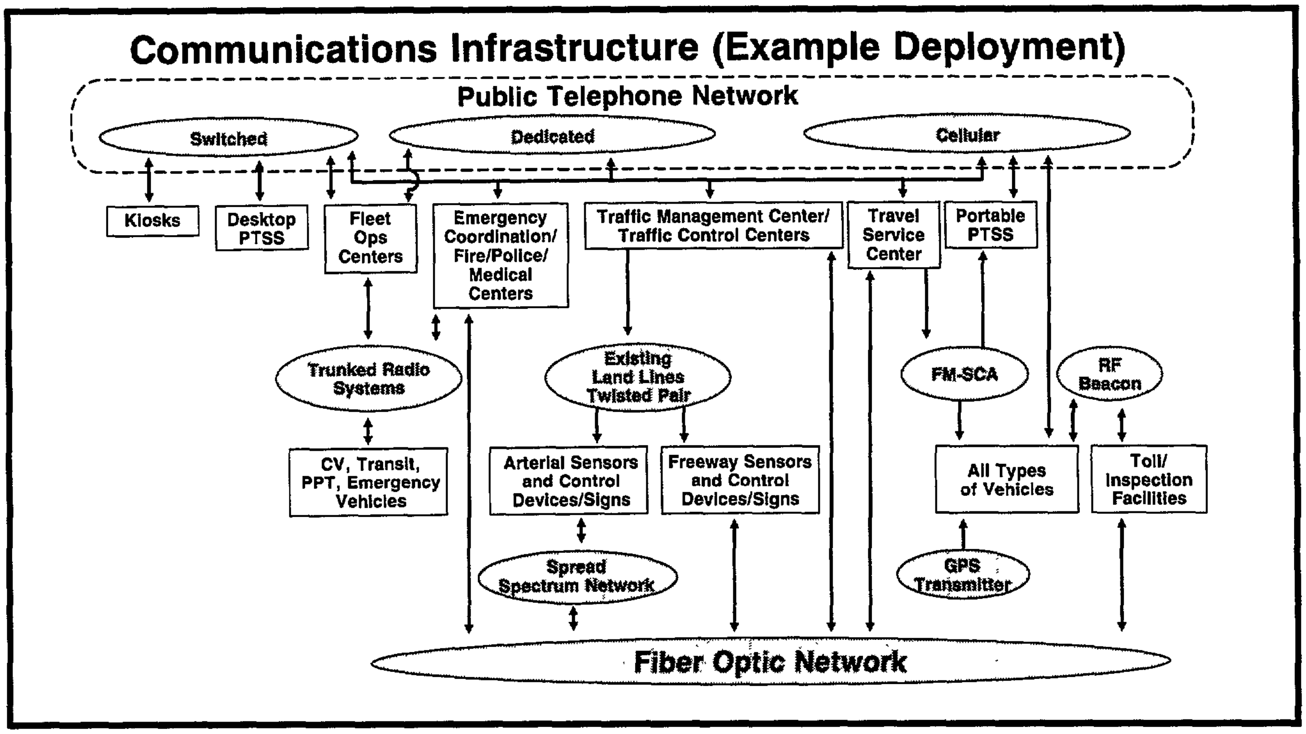


Figure 15. The communications infrastructure is largely existing, as shown in this typical urban deployment.

backbone when direct hookup is not practical. FM sidebands using existing radio stations are available for traffic advisories, while the stereo pilot signal can be used for vehicle location. Differential GPS provides higher accuracy location capability when desired. Localized FM or short-range roadside beacons provide in-vehicle signage and HAR, while long range RF systems (typically cellular phone and data networks) provide Mayday services and travel planning data. Fleet operators will use their existing trunked radio systems. Much of any new communications infrastructure will have to be made available by the Transportation Infrastructure Providers.

Partnerships: The Westinghouse architecture encourages public-private cooperative ventures. It not only creates the environment for new or expanded markets (e.g. subscriptions from System #6 - Public Travel Services), but it facilitates truly cooperative services, such as privately operated PPT services acting as feeders to the publicly operated mass transit systems. Provisions also exist for the cross-sharing of information across functions, thus providing financial incentives to participate where none existed before. In the above example, the TMC may provide travel time updates to the Public Travel Services System, which sells it's services to premium subscribers. Another example is the use of FM-SCA for vehicle data, which provides opportunities for FM broadcasters to form partnerships with the local DOTs.

Standards/Compatibility: Maximizing compatibility with existing infrastructure explicitly means adopting (to the extent possible) current standards and protocols. New technologies and applications will lead to replacements over time, and there is a well defined process for this. In addition, the architecture is designed to encourage the adoption of standards which will ensure nationwide seamless operations. The interface between the vehicle and the infrastructure has been simplified to **aid** this process. Broadcasting data to the vehicle is a standard operating mode. Much of the traveler information processing can be done on-board, depending on the options chosen by vehicle owners. Compatibility is required only to the extent that a service is offered, and the system can still work (albeit in a degraded fashion) if a given local infrastructure does not offer a particular service. Universally available techniques are used for Mayday, electronic toll collection, in-vehicle signing, and vehicle location, to name a few areas of interest.

Operations & Maintenance: Our architecture emphasizes minimal lifecycle costs for operations and maintenance (O&M) by using existing infrastructure whenever possible. We estimate that O&M costs will represent less than 25% of government outlays, compared to as much as 50% or more today. We further encourage optimization of life-cycle costing to facilitate investment decisions. Similarly, standardization will reduce maintenance, training, and other operating costs.

The O&M roles and procedures of the infrastructure providers are partitioned along the lines of the existing organizations, since our systems respect existing organizational structures. Therefore, there are no major shifts in O&M roles. The newer technologies will require a slight expansion of procedures, to accommodate additional communications and processing equipment.

System reliability should increase substantially with a deployment of our architecture. For example, video cameras gradually replace loop detectors, and are considerably more reliable and easier to install and access. Newer processors will be more reliable than those they replace.

Most equipment is off the shelf, and has been extensively tested by the market place or in operational tests. Since new infrastructure is minimized, there is little increase in complexity, which also means higher reliability.

Support for Policies: The architecture is structured to support any reasonable policy established by local policy makers. Travel demand management is supported, and may be implemented in many forms. This will help to ensure acceptance with widespread deployment, and therefore lowers risk and costs.

FREIGHT OPERATIONS

HUGHES

Weigh-in-motion systems eliminate the need for most commercial trucks to have to pull off into weigh stations to have their weight checked. As the truck approaches a weigh station it is weighed as it drives over an in-road scale. The weigh station computer communicates with the truck via the tag/beacon, to retrieve the licensed weight for the truck. If there is a discrepancy, the weigh station turns on a red light on the truck's tag, signaling the driver to pull into the weigh station; a green light signals the driver that he can by-pass the station. There are two implementations for doing the retrieval because no standard has been set yet. The Advantage I-75 implementation retrieves a truck ID from the tag, and uses this ID to retrieve the licensed weight from a database maintained by that State. The other implementation stores the licensed weight in the truck tag, eliminating the database retrieval. The Hughes Team Architecture assumes the in-tag implementation because this is the decentralized approach and therefore is not vulnerable to a nation-wide failure; however it requires future tags to be able to store different licensed weights in different States.

The Architecture assumes that trucking companies install Route Guidance Computers in their trucks to improve their efficiency. Given the location of the truck, provided by GPS, and a destination, the Route Guidance Computer selects the fastest route, considering preferences such as avoiding toll facilities, height/weight restrictions, and HAZMAT restrictions. The Route Guidance Computer utilizes real-time traffic information broadcast by the Traffic Management Center (TMC) in selecting the fastest route.

The Hughes Team Architecture specifies route guidance vehicles to be autonomous, selecting their own routes and re-routing to avoid congestion. However the Architecture accommodates truck fleet dispatchers who wish to do route selection in their control center in support of Computer Aided Dispatch. The dispatcher can provide the Just-In-Time customer with a reliable estimated time of arrival of his delivery by use of the same route selection computer used originally to develop the route for the driver to follow. Truck tracking is used to verify that the driver is following the selected route; the route selection can be re-run for the driver if he has had to deviate from the selected route.

Trucks are tracked with a cellular phone and a GPS receiver which automatically call the dispatcher at preset times. Another approach is to use the virtual beacon concept, but with the vehicle calling the dispatcher instead of the TMC when the vehicle is at preset locations; for example, this gives the dispatcher the opportunity to re-direct a truck leaving a delivery site.

The TMC provides traffic advisories to all vehicles via the same tag and the same beacon used for communications between vehicle and weigh station.

The truck container ID is stored in a tag affixed to it; this tag contains a summary of the data stored on cargo tags within the container. All of this data can be read via tag/beacon communications at any beacon location including border crossings, truck yards, container storage yards, port authority yards, airports, and ships. Truck stops across the country provide LEO phone service to transmit tag ID and location to the truck dispatchers.

The tags used by the railroads to track train cars and the tags used for trucks and for cargo will be functionally identical. The same tags are used for air cargo and containers and for ship cargo. This enables the emergence of a seamless tracking system for cargo and container equipment for the entire transportation system. Competition-sensitive information stored in these tags must be encrypted to prevent theft of business information.

Border crossings are further expedited by the use of tags affixed to the truck cargo and to the container to implement a “Line Release Program”. This program enables a shipper to make multiple shipments of the same item and to “close the customs books” once a month rather than at each border crossing. The tag would store the identification of the item covered by the Line Release Program, and the number of those items on the truck.

<u>The benefits of the Hughes Team Architecture are:</u>

1. Greater efficiency results from the weigh-station bypass, the use of route guidance, the expediting of border crossing, and the traffic advisories provided by the TMC.

2. Greater customer satisfaction results from successful Just-In-Time deliveries, and the ability to track cargo seamlessly across multiple carriers.

3. Increased safety is a result of the congestion management and driver advisories provided by the TMC, the collision warning and avoidance equipment, and on-board sensors monitoring driver alertness, truck malfunctions, and shift in cargos.

4. More efficient operation by shippers as a result of cargo tracking.

5. More efficient operation by regulators as a result of the weigh-station bypass and expedited border crossing operations.

See Product and Services Providers for Package availability and Preliminary Cost, page 101.

STAKEHOLDER-SPECIFIC INTERESTS

Privacy; The driver is concerned that the weigh-stations are programmed to determine his speed by monitoring the times at which he passes successive stations and that he will be ticketed for speeding. However, the communication between driver and weigh station need not include the driver's ID, since this communication is concerned with truck owner or carrier ID.

The truck owner is concerned that competitors will be able to gather business-sensitive data by interrogating tags from the side of the road. The Architecture accommodates use of an encryption scheme for data in the tag.

Policy and Regulation: One form of state truck tax is dependent upon the product of distance traveled in the State and licensed weight of the vehicle. This is called a weight-distance tax. It could be levied on the basis of data which could be made available at the weigh stations where the truck entered and exited the State; this would be a State choice, just as it is now, and would replace a manual log-book maintained by the driver, saving administrative effort. The Architecture accommodates this tax and the more common fuel tax.

Comuatibility: A common tag/beacon communication'protocol must be used nation-wide to be accepted by the trucking industry. The Advantage I-75 Program and the HELP Program are both being evaluated and it is expected that a common approach will evolve.

The common tag is the key to weigh-station bypass, traffic advisory messages, identification of cargo and truck for tracking purposes, and electronic toll collection.

LORAL

In the *five* year timeframe, ID/toll tags will be in common use for weigh-in-motion stations in some corridors, with drivers and fleet management centers beginning to do documentation and payment authorization via electronic data interchange (EDI). Large trucking firms will continue to have their own Fleet Management Centers (FMCs) and independent FMCs will sell services to small independent truckers. FMCs will be offering services via telephone to drivers who don't have mobile equipment beyond an ID/toll tag. Also, carriers will be beginning to provide planned HAZMAT transport routes to emergency management centers (EMCs) to accelerate appropriate emergency responses.

In the ten year timeframe route request, document processing, and preclearance/permit/fee transactions will all be available via remote transactions from FMCs, vehicles, and kiosks. Support for intermodal coordination will be universally available through ED1 and FMCs, for tight coordination with rail, water, and air transport. It will be possible to electronically log vehicle and trailer safety conditions. Vehicles that make this on-board safety data available to the roadside, upon authorized request, will receive in-motion safety checks.

In the twenty year timeframe all freight operators, regardless of size, will be able to obtain electronic forms processing support from FMCs, as well as route planning, preclearance, intermodalism, and all other required services. Many fleet management centers, having long supplied the functions in-house, will be successfully marketing these services as stand alone ISPs in markets that do not compete with their core businesses. Driver safety conditions will begin to be sensed and provided upon authorized request. The widespread use of on-board safety monitoring and EDI will aid state police in providing better, not broader, regulatory enforcement.

Low CVO with an ID tag

In the Loral Architecture the ID tag is the only required piece of in-vehicle equipment for access to the advanced CVO (Commercial Vehicle Operations) services. Commercial truckers can bypass roadside stations by preclearing via phone through an independent FMC, or by having their fleet operator/dispatcher preclear them. Truck drivers may also do their own preclearance at a kiosk in a truck stop, if available. Truckers with a portable computer equipped for wireless communication will be able to do all paperwork electronically from the vehicle. Then, using only an ID/toll tag, the vehicle is identified at the roadside station, its records are checked, and then it is cleared to pass the station or asked to pull in (Figure 16).

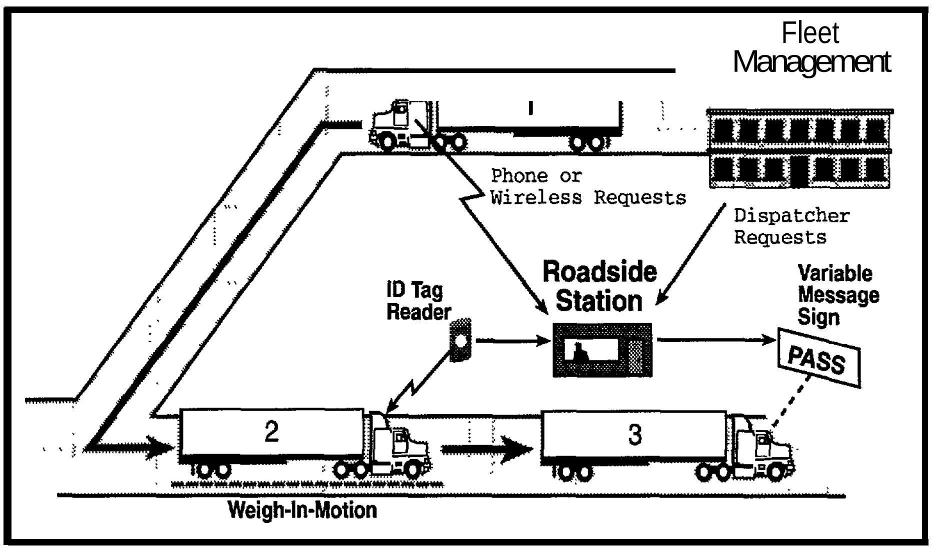


Figure 16. The Loral Architecture supports ID tag-only CVO preclearance.

The Loral team firmly believes that electronic data handling is best done using the existing communications infrastructure, as an interaction between entities such as the fleet management center and the roadside station. This will prove most cost effective: by keeping the data in the infrastructure, we keep the infrastructure out of the trucks, lowering the cost.

PRIVACY

Sensitive information communicated between subsystems, or stored in the subsystems, is protected by encryption and authentication processes. Minimal data is stored on-board vehicles, and no vehicle data — aside from the ID tag can be accessed without authorization. These measures ensure that confidential business or personal data is not exposed to unauthorized access, eavesdropping, or interception. The Loral Architecture also does not require vehicle position or driver status monitoring; these functions can be implemented as an individual choice if warranted by the benefits (for example, to receive improved services or reduced insurance rates). The Loral Architecture protects the user's perogative to maintain or reduce privacy by choice.

POLICY & REGULATION

The Loral Architecture holds the promise of tremendous increases in the efficiency of policy implementation and CVO regulation. This results from the emphasis on ED1 and automation. Government regulators, enforcers, and commercial entities all stand to benefit. To spur acceptance of the technology which will increase the efficiency of the regulatory process, the Loral team believes commercial vehicle participation should be voluntary. Once the economic benefits of the ED1 and automation are clear, government and private support will be strong. It is in everyone's interests to support technologies and policies that reward regulatory compliers and identify violators.

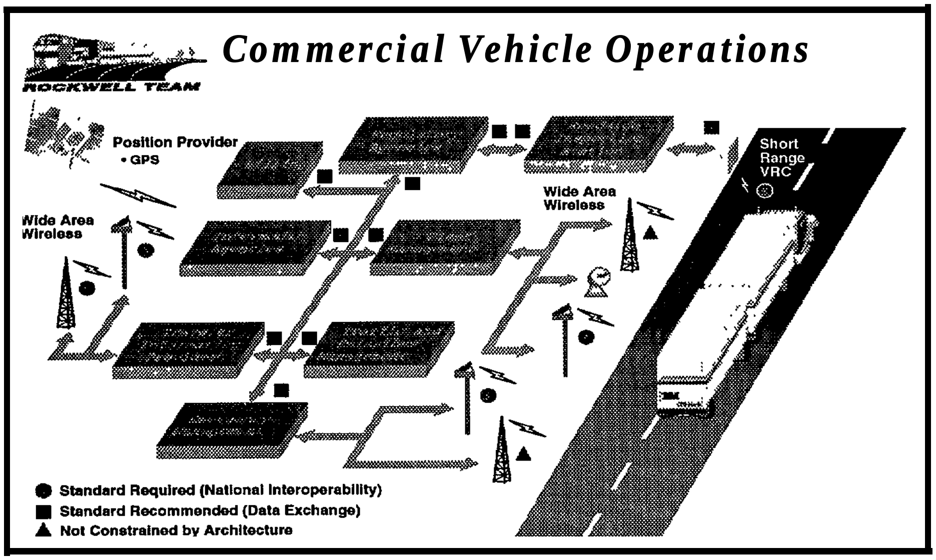
STANDARDS/COMPATIBILITY

The Loral Architecture emphasizes the use of existing communications options, infrastructure, and standards. For example, the single ID/toll tag preclearance model is compatible with some of the existing electronic preclearance and weigh-in-motion systems. Future deployment and acceptance will be enhanced, however, if a uniform, accepted standard for the automated vehicle and equipment identification tags is selected. The Loral Architecture can accommodate whichever tag standard the market ultimately favors.

The Loral Architecture identifies required data messages for communications between the Roadside, Vehicle, Remote ITS Access (for kiosk and government/regulatory agencies), Independent Service Provider, Emergency Management Center and Fleet Management Center subsystems. Standardizing these message formats is critical for nationwide compatibility and interoperability. In many cases, the existing or draft standards for ED1 will form the basis for these standards.

ROCKWELL

The primary subsystems that provide the services for Commercial Vehicle Operations are Fleet Manager, Roadside Inspection Station, Emergency Management, Transit Management, Billing, and the Commercial Vehicle. The Regulatory Agencies and Intermodal Transportation Providers are external entities to the architecture. The most important elements to Commercial Vehicle Operations are the Fleet Manager and the Regulatory Agencies. The Fleet Manager has the responsibility of dispatching and managing the commercial vehicle fleets, providing instructions and coordination to the commercial vehicles, handling preclearance registration, and monitoring the status of the commercial vehicles. The Fleet Manager also interfaces with the regulatory agencies. A standard at the application layer interface is recommended to facilitate the exchange of database data.

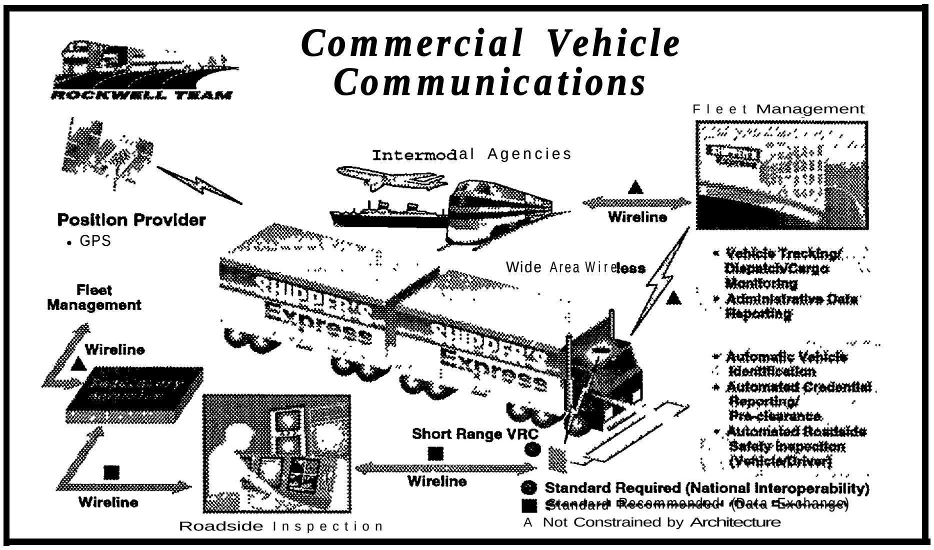


The Regulatory Agencies are responsible for regulating commercial operations and are an integral part of the market packages because of their direct involvement with issuing licenses, permits, and other credentials for preclearance. They provide database information to support most CVO services and will receive, distribute, and audit CVO related taxes.

While the information interaction between all infrastructure subsystems will be by wireline, communications with the Commercial Vehicle will be by both short range vehicle-to- roadside and wide area wireless. The short range vehicle-to-roadside communications are used for transmitting preclearance information and the results of onboard automatic safety inspections to the Roadside Inspection Station. If the vehicle is carrying hazardous material, this information is also passed through the short range VRC to the Roadside Inspection Station. In addition, vehicles carrying Hazmat will carry information regarding the safe handling of material in the event of an incident. A standard is required for the interface. As mentioned earlier, the standard being developed for toll payment, should be expanded to include the requirements for roadside inspection, to reduce the cost of having multiple types of communication hardware on the vehicle. The Rockwell Team architecture proposes that all toll collection agencies install equipment to support a national standard once it is developed and approved. Individuals can continue to use the installed system until it is gradually phased out over time. The cost of the replacement system can be easily offset with the collection of fees for use.

The wide area wireless cell-based communications can be used to report vehicle position, itineraries, fuel usage, cargo condition, and the results of automatic on board safety inspections. The Fleet Manager can use the existing systems, including satellite, cellular, or special mobile radio (SMR). If special services, such as local Traffic Information, Mayday calls, etc., are required, compliance to the architecture wide area wireless vehicle standard will be necessary prior to receiving such services. Eventually, a vehicle-to-vehicle communication standard will be required before the Automated Highway System is implemented. Communication with Intermodal Transportation Providers will be provided using existing wire line.

The incremental market packages provide the basis for the deployment strategy. The minimum market package contains vehicle tracking and dispatch. Additional capabilities can be added to vehicle tracking and dispatch to include credentials checking, materials tracking, and vehicle safety devices. Vehicle tracking and dispatch will be introduced in the 5-year time frame in the Urban and Rural areas, and will progress to the Inter-Urban area by year 10. Full deployment in the Rural area will occur by year 10 (rural is defined as an area travelled through by cross country long-haul commercial vehicles). The expectation is for full deployment in all areas by the 20-year time frame. The cost for these services when fully deployed are estimated to be $1,000 for in-vehicle equipment, with an annual recurring cost for the information link of $150, plus an annual operations cost of **$18** per vehicle.



Given the sensitivity of the information that will be communicated between the commercial vehicle and the roadside and between the commercial vehicle and the Fleet Manager, the architecture allows for a very flexible approach on the privacy and security of the information communicated. The Fleet Managers establish the policy for their fleet regarding automatic vehicle identification (AVI). When material (cargo) is being tracked or credentials are being checked, the regulatory agency will protect that information through secure information exchange(s). The architecture is imposing no new regulations on the fleet operators.

The architecture provides the framework, through the subsystem elements and the market packages, to introduce technologies for commercial vehicles (trucks, commercial fleets, intercity busses, etc.) that will allow automated, no-stop-needed handling of routine administrative tasks that have traditionally required stops and waiting in long lines: e.g. paying tolls, obtaining permits, weighing vehicles, etc. Through the implementation of the market packages that provide this automation, time can be saved, air pollution reduced, reliability of record-keeping and fee collection increased, and continued improvements in safety will result.

WESTINGHOUSE

Deployment-Oriented Specifics: All long haul freight operations are contained in System #8 (Commercial Operations System - see figure 17.) The availability of these services will obviously depend upon the willingness of the states to participate. Wherever offered, compatibility is assured by standards. The long haul trucking industry will likely use GPS for vehicle location because of its widespread coverage, and the architecture supports this. ITS vehicle equipment is essentially the same as that for the premium option offered to consumers, and is priced at $1300. See figure 11 on page 60. Specific long haul benefits have not yet been quantified, but they are obviously substantial due to the availability of preclearances and inspection on the fly. Short haul trucking is contained in the Personal Travel Support System, and is treated as a premium option commercial consumer, so that the ITS vehicle equipment price is still $1300. The urban ITS enhancements to System #8 consume about 5% of the total ITS cost. (No roadway stations are included in this cost, but dispatch centers and vehicles are.) See figure 8 on page 50. All freight operations will benefit from the enhanced performance shown in figure 17 below, especially the 13% reduction of vehicle mileage (less traffic), the 43% reduction in delay due to incidents, and the 33% reduction in crashes.

Privacy: As is the case with private consumers, freight operators may control their own level of privacy relative to flexibility and mobility. Again, this is a policy issue, not an architectural one. Of course, in this case company policies may well lead to more employer-imposed "control" over their employees, and the architecture will accommodate this.

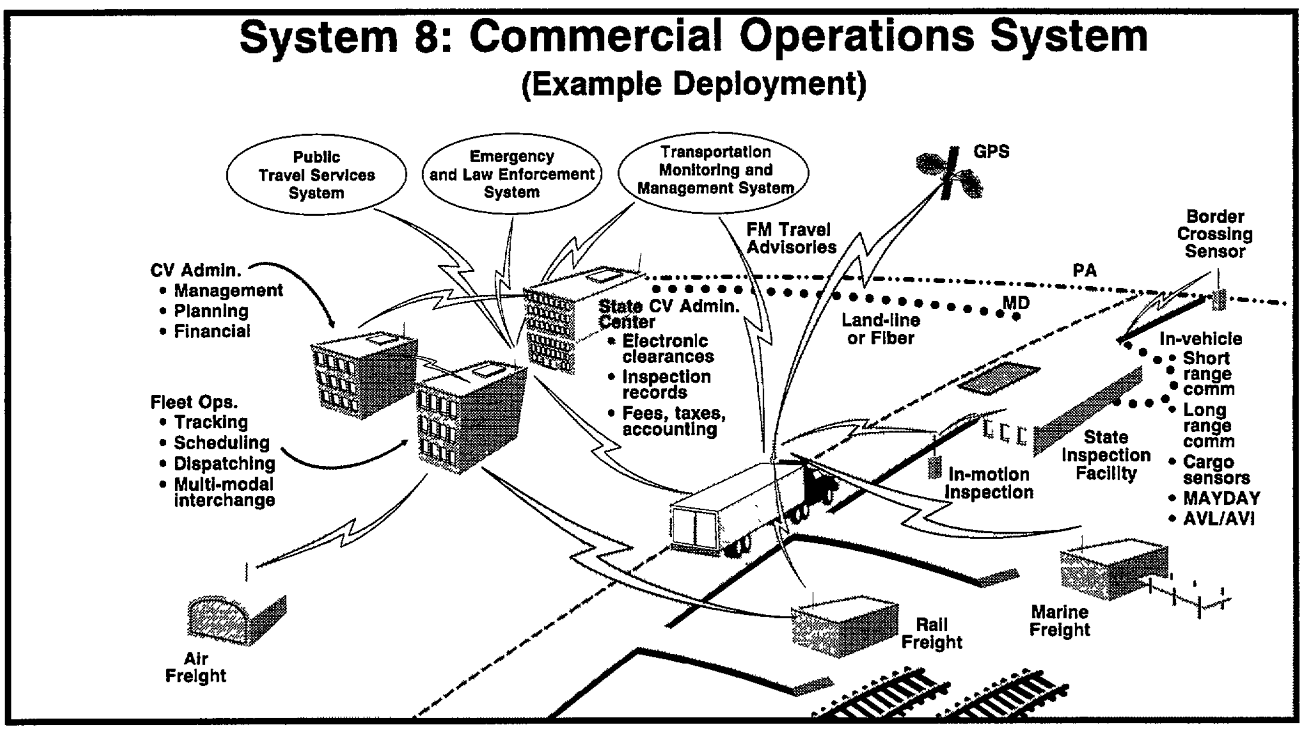


Figure 17. The Commercial Operations System (System #8) will significantly reduce regulatory costs.

Presumably of more concern to the motor carrier industry will be protection of private records. Again, the architecture does not dictate policies in this regard, but ours provides the ability to include security screens and filters to prohibit inappropriate access to these data.

Policy and Regulation: Automation of CVO functions is already and will increasingly ease the burden on both the industry and the regulators. Time saved in not making frequent stops at weigh and inspection stations will pay huge dividends to carriers. Automated weighing and processing will reduce inspectors and administrative costs on the government side. This is a classic "win-win" situation. Likewise, electronic pre-clearance and report filing will save costs for all involved.

Standards/Compatibility: As in the case of the infrastructure, maximum use is made of appropriate existing technologies and practices. This maximizes the compatibility of our architecture with existing products, services, equipment, and standards. In this case, we deal with a smaller segment of the traveling population, but one whose interest in safety, efficiency, and economy are considerable. Indeed, many major carrier firms are already managing fleets at a level the rest of the system will not likely achieve for five years, and they are already driving the establishment of standards. Yet, the small, private owner-operator can and may continue to operate existing equipment for years to come - again they will get what they pay for.

Safety: Concerns have been levied over safety, particularly truckers speeding to remain within their "time windows." While a short term concern, on-board safety and monitoring devices will rapidly allay these concerns. Safety is also enhanced by pre-planned responses and HAZMAT tracking, which the architecture explicitly supports.

PUBLIC SAFETY SERVICES

HUGHES

The response time of public safety vehicles is improved through the installation of Route Guidance Computers. Response time is also improved by pre-locating vehicles in the field at positions based upon historical data on accident occurrences; tow trucks circle around a stretch of freeway so that they can reach a stranded motorist by some maximum time.

Given the current position of the vehicle and the destination location, the Route Guidance Computer selects the best route to the destination. Current vehicle location is determined by GPS. Destination is provided by the emergency service dispatcher. The destination may reach the dispatcher from a vehicle transmitting a MAYDAY call; MAYDAY calls automatically provide their own location using the GPS system.

The Route Guidance Computer uses real-time traffic information broadcast by the Traffic Management Center (TMC) in selecting the best route. Information other than traffic conditions may have a significant bearing on the choice of the "best" route. For example, on the basis of police reports input to the route guidance computer, the route selection will not consider selection of routes which go through an area of civil disturbance or routes which have suddenly been blocked by a natural disaster.

Accidents involving the public safety vehicles are reduced by equipping these vehicles with collision warning and collision avoidance systems. Vehicle-to-vehicle radio systems alert vehicles ahead of the public safety vehicle to pull over - even if drivers of these vehicles can not hear the safety vehicle siren, possibly by taking control of the radio or tape or CD player.

HAZMAT trucks are equipped with tags which store chemical contents and instructions on how to handle an incident involving the truck.

Crime suspects pose less of a danger because police vehicles have head-up-displays. The officer can radio for information on the suspect and display it on his windshield; he can read this information without taking his eyes off of the suspect. This information includes visual images of wanted felons.

The benefits of the Hughes Team Architecture are:

1. Cost reduction is a result of achieving faster response time because this reduces the number of vehicles and personnel required.

2. Cost reduction is a result of the installation of Route Guidance Computers in the emergency vehicles because this allows use of less experienced personnel and allows personnel from another area to be brought in.

See Product and Services Providers for Package availability and Preliminary Cost, page 101.

STAKEHOLDER-SPECIFIC INTERESTS

Standards/Compatibilitv: Route Guidance databases must be standardized so that emergency personnel from different organizations can work effectively as a team.

Institutional Partnershins: Integration of Public Safety Service agencies significantly improves the effectiveness of each organization.

Public/private partnerships offer new opportunities for improving service. An example is a private ambulance service which is under contract to a local Public Safety Service agency and which is paid on the basis of how quickly it gets patients to the hospital.

LORAL

The User Services which implement Public Safety Services will be implemented in the near term. In the five year timeframe, cellular data Mayday and HAZMAT notification capabilities are in use. Automatic traveler location technology is deployed and used with cellular data emergency messages to the Emergency Management Center (EMC). The EMC to E-9 11 Center data interface is deployed in some locations, and 2-way data communications with emergency vehicles and AVL tracking of emergency vehicles is deployed. In the ten year timeframe some urban areas have deployed shortest time dynamic route planning for emergency vehicles with signal prioritization support from TMCs. In the twenty year timeframe most HAZMAT and many vehicles are able to send automatic Mayday messages when an accident has occurred and HAZMAT emergency pre-planning is in place through the CVO-HAZMAT constrained route selection process.

REDUCE EMERGENCY RESPONSE TIME

Our safety analysis shows that reduction in the time between the occurrence of an injury accident and the arrival of medical help can have a substantial impact on survivability. In the twenty year timeframe, emergency vehicles will have their routes selected by ISPs, and those routes will be communicated to the TMC Traffic Management service package for priority signal service and earlier arrival at an emergency site (See Figure 18). In addition, rapid data-based deployment of emergency response vehicles via the Emergency Management Subsystem will get help to incidents faster, and will enhance traveler safety as a direct consequence.

REDUCE CONGESTION AND IMPROVE SAFETY

By using demand management tools that the architecture makes available to local public agencies, congestion can be reduced, thus reducing the number of transitions from free-flow to stop-and-go traffic conditions. These transitions have been identified in our preliminary safety analysis as a significant cause of traffic accidents.

FAIL-SAFE INFRASTRUCTURE ARCHITECTURE

The Loral architecture has not allocated any safety critical functions to the infrastructure. Vehicle control (for collision avoidance) remains entirely within the vehicle subsystem, and in the case of platooning and AHS related functions, is based on communication directly between adjacent vehicles.

In the event of a total infrastructure failure, signals would fall back to local sensor based signal control or fixed time plans, exactly as they do today. Thus the worst consequence of a total infrastructure failure is traffic congestion.

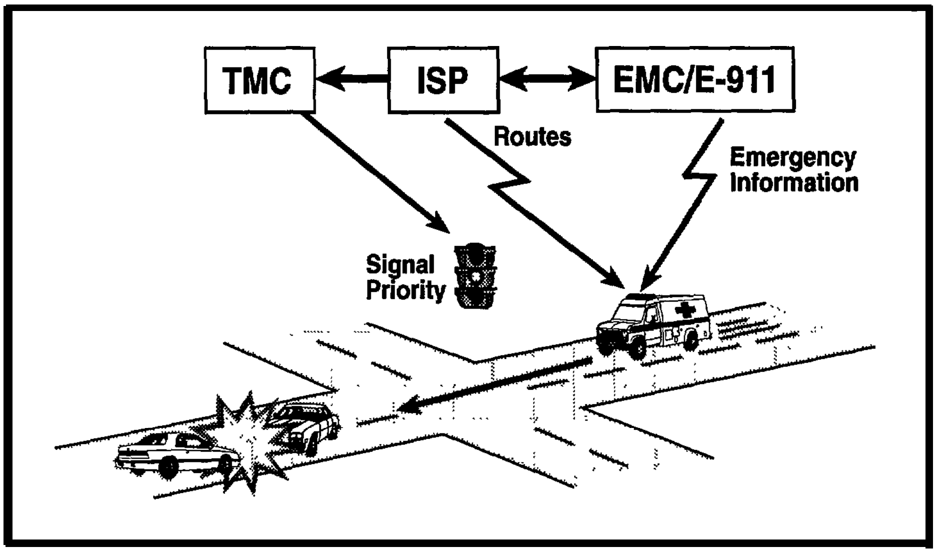


Figure 18. Reduced Emergency Response Time will Save Lives

EMERGENCY MANAGEMENT CENTER PARTNERSHIP WITH E-9 11

The Loral Team has developed an interface between the ITS Emergency Management Center (EMC) function and existing E-911 services. E-911 is the telecommunications interface for traveler and other emergency requests, and the EMC augments that function with an ITS architecture supported traveler data interface.

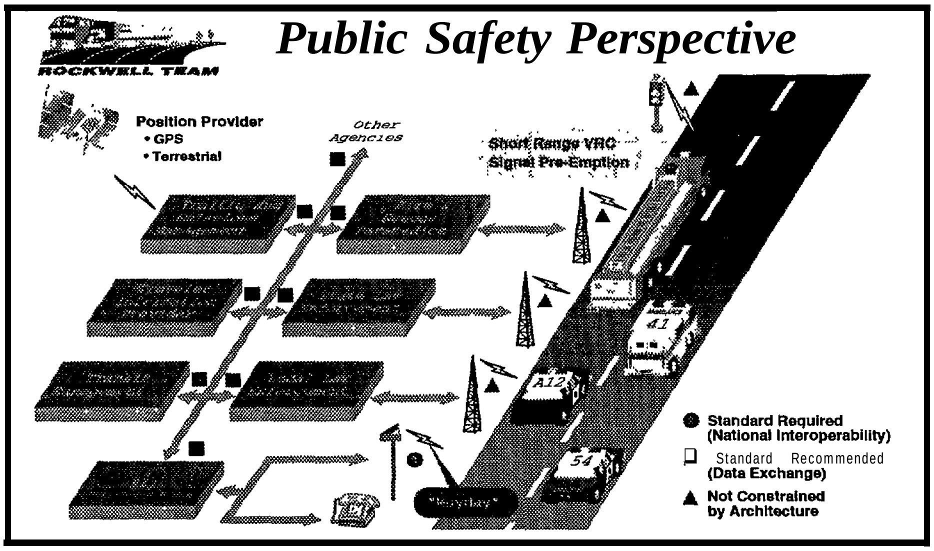
The ITS EMC is an emergency "data" interface to travelers. E-911 is a telecommunications (voice) interface to callers. The purpose of the E-911 to EMC interface is to enable E-9 11 and EMC dispatchers to share the status of emergency data and voice calls including location, response status, ETA, and other information pertaining to the incident and the planned response. When an E-911 center incorporates the EMC functions, the E-911 dispatchers capabilities are substantially enhanced, allowing them to allocate a greater percentage of their time to the telecommunication interface with callers.

ROCKWELL

Public Safety benefits from the Rockwell Team architecture by making use of common communications media, interface standards and improved data availability. Public Safety Market Packages which are available through the Rockwell Team architecture include products for the general public and specific products for emergency service providers. Market Packages for the public include a low-cost Mayday device option ($73, which is included with other 2-way communication devices for a nominal service fee ($12/year). This device provides the user's location along with the distress message. This location may be either based on an on board GPS (part of full function ATIS route guidance package of up to $1420 including the radio) or a terrestrial location system. Additional packages which will be available in the near future include advanced driver safety ($150 in 10 years) and vehicle safety devices ($1000 in 20 years), which automatically determine the nature of an emergency and include this information in the Mayday signal.

These Mayday signals arrive as E-9- 1- 1 reports at the Emergency Management Center through the wireline and wide area cell-based infrastructure. Because the information is transmitted as digital messages in a standard format, the data can be exchanged with TMC's as well as forwarded to other EMC's, appropriate commercial agencies, and the media, and coordinated with Transit Management Centers when necessary. Roadway incidents can be similarly reported using congestion monitoring devices, including loop detectors, cameras connected to a Traffic Management Center, and probe vehicle data collected by a Traffic Management Center, or by a private Traveler Information Provider.

Market Packages for the Emergency Service Providers include route planning similar to that available to private vehicles. The Emergency Management Center may coordinate with Traveler Information Providers, providing advisory and route planning services to the private vehicles. They may recommend routes which will avoid the incident location and for emergency vehicle access. The routing recommendation may actually be performed by the private Traveler Information Service Provider or by some central Emergency Dispatch Center, as the architecture allows this routing service capability to exist in any center. The architecture allows this to happen by distributing congestion information and advisories over the wireline infrastructure from the collection points to subscribers. The wireline fiber optic infrastructure also supports the display of live video of several incidents working simultaneously from cameras installed on the roadway.



Emergency Management Centers, including police and fire stations, search and rescue, special detachments, and central dispatch centers, are inherently more distributed than other public ITS related operations. They may therefore realize the significant benefits of having standardized data and message formats to achieve virtual co-location of cooperating entities. This co-location has real potential but is expected to require some effort to get going, including up to $500K total startup costs per station, including the initial installation, consultants, training, linkup to installed video wireline infrastructures to receive live video from incidents, and the computers and software to track vehicles and manage data exchange.

The architecture does not attempt to replace existing communication interfaces. It encourages the retention of alternate communication paths for emergency services to support the response to incidents which may interfere with the normal infrastructure. For a large portion of the Emergency activities however, the existing wide area communication links provide enhanced capabilities to exchange information between emergency vehicles and their dispatch centers. Because of the expected broad market for in-vehicle graphics devices to display roadway structures, graphic devices for emergency vehicles should be inexpensive and should provide the display of tactical situations, design data for structures and vehicles, and visual procedures. All of these facilities should be able to utilize the basic in-vehicle graphics, which are used for route planning ($1420), and the wide area cell- based 2-way communication links. Air time is estimated to be about $440/year.

Overall, Emergency Management services are integrated with all ITS entities, from private driver safety and Mayday, to route planning and coordination, to Hazmat vehicle tracking and incident clearing, to automated violation detection and recording. Installation of the Emergency Services infrastructure is key to the successful deployment of ITS services. The architecture supports existing communications and procedures and includes the additional capabilities to use shared information and technologies to improve incident response and management of emergency fleet resources more efficiently and effectively.

WESTINGHOUSE

Deployment-Oriented Specifics: Public safety services are provided by System #3 (Emergency and Law Enforcement System - see figure 19). The Emergency Management Coordination and Administration Center interfaces with all of the existing public safety services. Along with ITS upgrades to existing vehicles and centers, it constitutes the bulk of the cost of the ITS enhancement to System #3, which only consumes 0.5% of the total ITS cost. See figure 8 on page 50. The EMCAC is structured to reduce false alarms and incident response times. As figure 9 shows, we achieved a 43% decrease in delay **time** due to incidents. This is accomplished by a reduction in both the incident response time and the number of incidents. The total response time in the urban scenario is reduced by two minutes. This is achieved by better pre-planning, better incident identification, and better communications. The two minute reduction decreases the traveler delay by 10 minutes, and accounts for 10% out of the overall

43% reduction. (Thus, 33% out of the overall reduction is due to fewer incidents.) In addition, lowering false alarm rates substantially increases system effectiveness and lowers operating costs for all emergency systems.

Standards/Compatibility: The architecture is completely compatible with all existing services, equipment, and standards, since it provides a separate EMCAC to interface with existing systems. New standards will be required for communications protocols and formats, especially Mayday signals.

Partnerships: Institutional autonomy is completely preserved, which should enhance acceptance of the architecture by existing organizations, public or private. The EMCAC will substantially increase cooperation and coordination of existing public and private systems, since that is its primary function. The center offers another opportunity for a public/private partnership.

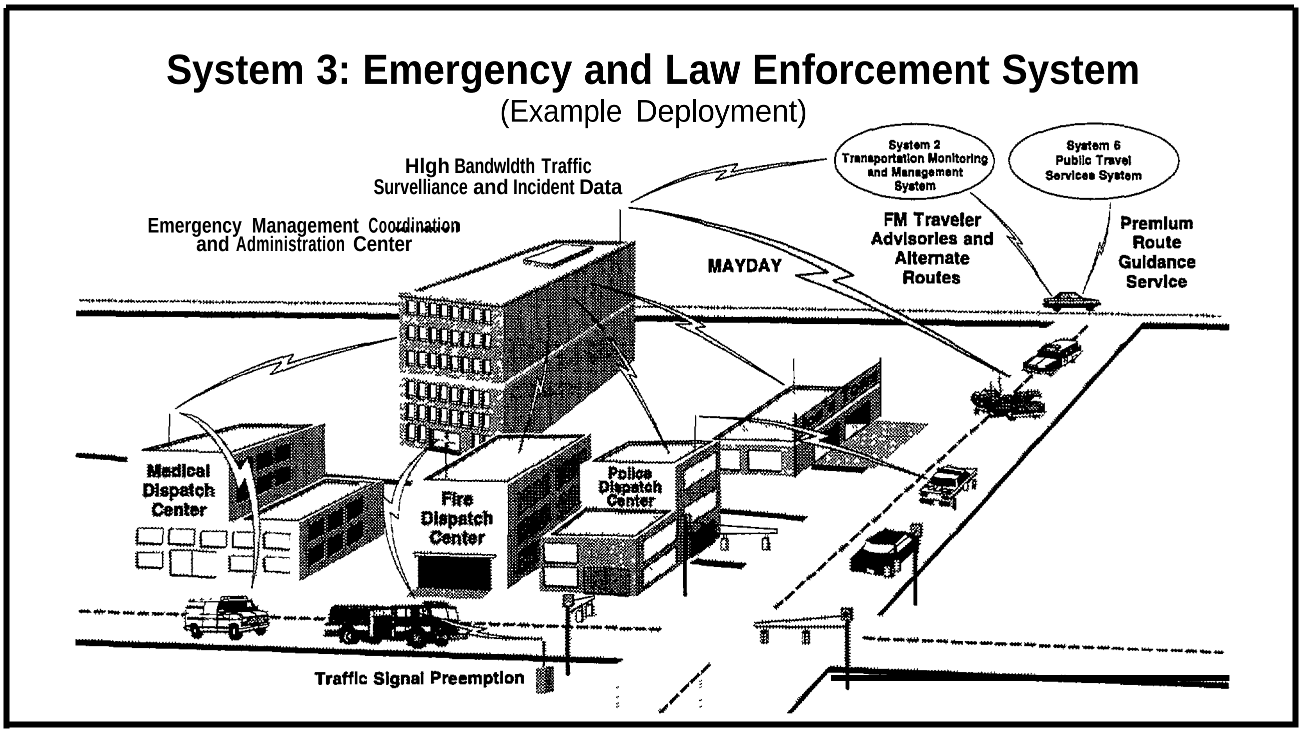


Figure 19. The Emergency and Law Enforcement System (System 3) is focused on an Emergency Management and Coordination Center.

PASSENGER OPERATIONS

HUGHES

Riders depend upon transit agencies to provide service on schedule and to take prompt action to recover from anything which interferes with maintaining that schedule. The Agency makes the actual schedule information available, in real-time, to travelers doing pre-trip planning at home, office, kiosk and bus stop.

Buses keep to one of two schedules: a “headway” schedule or an absolute time schedule. Headway scheduling concerns itself with maintaining a particular separation between buses arriving at each bus stop. (E.g., buses arrive here every 5 minutes during the rush hour.) An absolute schedule concerns itself with maintaining particular arrival times at each bus stop.

Both types of scheduling are monitored by the same type of tag/beacon communications system used by the Traffic Management Center (TMC) to deliver travel advisories to vehicles and to collect travel time measurements back from the vehicles. The Hughes Team Architecture accommodates the sharing of actual beacon installations between the transit agencies and the traffic management agencies.

Headway control is monitored by each bus storing its ID and the current time in a beacon installed at each bus stop. Each bus reads the time of arrival of the bus preceding it, computes the current headway between the two buses, and displays the headway time to the driver who can then speed up or slow down to correct the headway. Absolute schedule control is monitored by the tag reading the ID and current time from the roadside equipment at each bus stop and comparing this result to the correct schedule. In each case the results of the monitoring is known directly by the driver. The dispatcher retains the capability to adjust schedules, leap-frog one bus ahead of another, etc.

The service provided by flexible-route buses is improved by the use of a Route Guidance Computer in the bus and a route selection system in the dispatch center for use by the dispatcher in conjunction with a Computer Aided Dispatch system. The route selection system enables the dispatcher to determine the best route for each of the buses to pick up and deliver the travelers who have requested service. The local Traffic Management Center (TMC) provides the route selection computer with real-time traffic information, enabling the routing to be based upon current traffic congestion.

The dispatcher is able to call the bus via cellular phone and to transmit a re-route to pick up another patron or to avoid traffic congestion just reported by the TMC.

The use of a route selection computer by the dispatcher, and a Route Guidance Computer in the taxi makes the taxi operation more efficient. The use of this equipment and the advantage of having real-time traffic information from the TMC would be very similar to the description, above, for the flexible route bus.

The Hughes Team Architecture facilitates multi-mode travel. Route selection systems, in use in Route Guidance vehicles, and available via interactive TV at home, office, and kiosks include transit schedules and can, at user request, determine the best route based upon both private vehicle and transit or either one by itself.

One function of the tag/beacon communications link is to transmit roadside sign information into the vehicle for display to the driver. The transit agencies use this function to announce freeway exits which lead to park and ride facilities. Sign information includes transit destinations, next departure time, and availability of parking.

Bus stops and transit stations have built-in interactive TV displays which allow the traveler to “see” where his bus or train is along its route, and to see other possible transit routes to choose from. Ride sharing is encouraged by a ride-share network on the Interactive TV which facilitates driver and rider finding each other.

Design of the bus routes is continuously reviewed to provide the optimum service to travelers. The use of pre-paid cards for paying the fare on a bus enables the transit agency to maintain an Origin/Destination (O/D) database on bus patrons. This is done by writing a bus stop ID into the card when the patron gets on, and comparing it to the bus stop ID where he gets off.

<u>The benefits of the Hughes Team Architecture are:</u>

1. Improved adherence to schedule.
2. More effective operation of flexible route buses and taxis.
3. Opportunity to reduce costs by sharing beacons with the Traffic Management Agencies.

3. Opportunity to reduce costs by sharing beacons with the Traffic Management Agencies.

See Product and Services Providers for Package availability and Preliminary Cost, page 101.

STAKEHOLDER-SPECIFIC INTERESTS

Standards/compatibility: Standards are needed for the pre-paid cards, since these are used to pay for multi-mode travel. The use of GPS, cellular phone and tag/beacon communications is a break in compatibility with traditional two-way radio communications.

O&M The switch from traditional two-way radio communications to cellular and tag/beacon result in lower life cycle O&M costs.

LORAL

In thefive year timeframe, public transit schedules will be available on-line and wayside locations will begin to support real-time schedule information display. Operations and maintenance for fleets will be dynamically scheduled, to make the most efficient use of facilities while also increasing vehicle reliability. Surveillance of transit-stop queues and vehicle occupancy for route and schedule planning will enter the early testing stages.

In the ten year timeframe technology will be in place for dynamically maintaining transit schedule integrity in cooperation with transportation management centers (TMCs). Dynamic ride matching services will be widely in use and accepted, benefiting from private independent service provider (ISP) packaging and coordination with private and public transit options. Flexible paratransit scheduling and service supported through public and private entities will be commonplace and critical to the significantly enhanced convenience of multimodal transit. Monitoring vehicle condition, incidents, and alarms will be performed for safety; waiting-area queues will be under surveillance for scheduling and security.

In the twenty year timeframe all modes (including rail, sea, and air) will be integrated for scheduling, fare payment technology, and trip planning. Sophisticated signal priority will be given to speed up specific transit vehicles that are falling behind on their schedules or to improve overall transit performance to enhance its attractiveness. Travelers can obtain real-time multimodal transit information from many sources and can make reservations and pay fares seamlessly across all modalities.

STANDARDS/COMPATIBILITY

The Loral Architecture identifies specific data message standards requirements for communications between the Public Transit Center (PTC), Traffic Management Center, ISP Roadside (the subsystem that supports “bus stops”), Vehicle, Personal Traveler Guidance, Remote ITS Access (e.g. kiosks), Independent Service Provider and Emergency Management Center subsystems. These standards are critical to the effective dissemination of information to travelers and for coordination across transit modes and jurisdictions.

Public transit planners will be able to choose from vehicle communications systems based on beacon communications for fixed route urban applications, cellular or Specialized Mobile Radio (SMR) channels. Cost effectiveness and availability will be the deciding factor for selection.

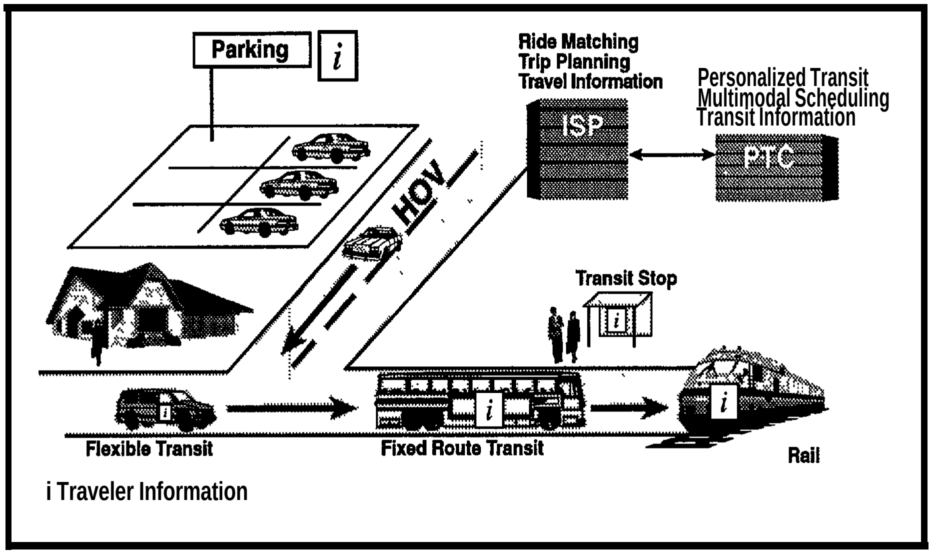


Figure 20. Broad access to real-time travel information will be available to passengers

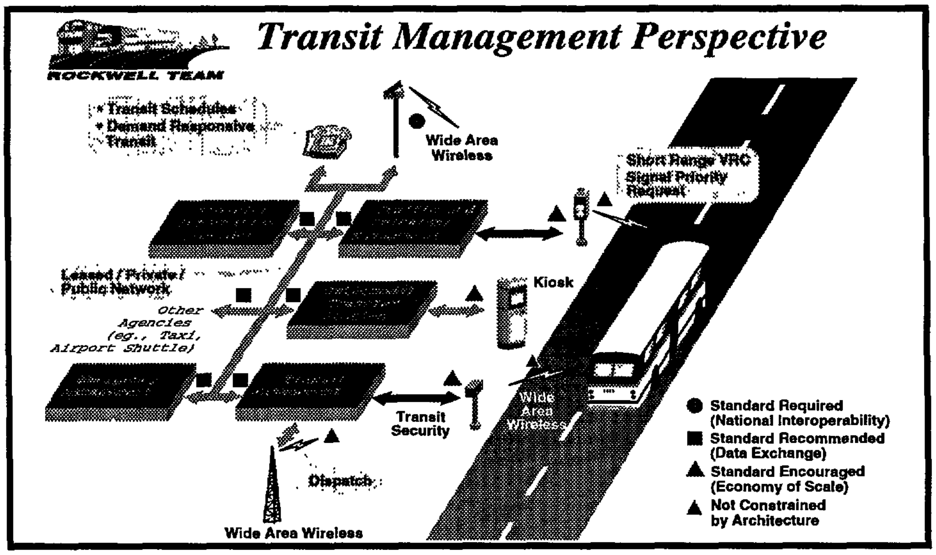
OPERATIONS & MAINTENANCE

The Loral Architecture emphasizes public-private partnerships to make deployments affordable and to control operations and maintenance costs for public agencies. A key architecture feature is that the potentially complex communication infrastructure can be operated and maintained by private communications service providers and, for beacon systems, by Roadside ISPs (private entities that operate some of the roadside functions) Several other roadside functions, such as kiosks, bus stop information, or surveillance systems have been allocated in the architecture to Roadside ISPs, indicating that there is potential for these functions to be provided by private industry to the public transit agency. Transit operators would then purchase services and information, rather than operate these systems.

The operation and maintenance costs for transit agencies and private transportation providers will be focused on the vehicles and the equipment in the PTC, as they are currently. The architecture-based standards should develop an industry which competes to supply the common needs of public transit entities, increasing the affordability of these services. The Loral Architecture also emphasizes modular and scalable deployment to allow transit agencies to select appropriate capabilities and to deploy critical early systems, and to do this without risking later incompatibility when new capabilities are needed to satisfy new needs.

ROCKWELL

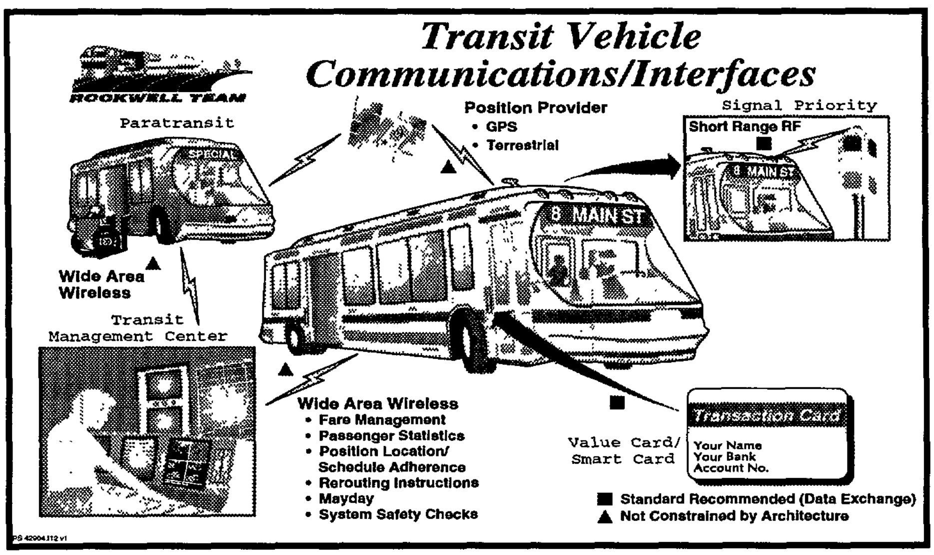
The Transportation Layer for Transit Management uses the same network and recommended interface standards as discussed previously. Areas of additional interest include presentation of schedule information at kiosks and the payment of fares using a value or credit card. The architecture encourages a standard interface to kiosks and recommends that a standard should eventually be developed for the payment of fares, not only on buses, but for all modes of transportation, as well as for other transactions.



The Communications Layer for Transit Management includes short range VRC to request signal priority when running behind schedule, and wide area wireless for two-way communications with the management center. The two-way wide area wireless is used to allow in-vehicle and central management of passenger loading and fare payment, vehicle tracking, security, and vehicle condition monitoring. Since transit systems do not require national interoperability, the architecture does not require that these communications media meet a national standard. Instead, the architecture accommodates existing infrastructure and enables local jurisdictions and their agents to select the best communications media that supports their needs and fits their budget.

Passenger operations are best represented in the Rockwell Team's architecture through a bundle of market packages oriented toward Advanced Public Transportation Systems (APTS). Taxis, Shuttles, and privately operated passenger operations are not included here. Instead, they are addressed under the Fleet Operations collection of services.

These market packages are designed to provide automation of operations, maintenance, and vehicle safety and security monitoring activities at a transit management center. They also provide real-time information on vehicle location and vehicle operations back to the management center. Components of these market packages are presently undergoing initial deployment in a number of urban areas across the country. Accordingly, the evolutionary deployment strategy for the architecture emphasizes early development and deployment of these market packages (particularly within the 5-year time frame), allowing early realization of benefits of these types of services.



The benefits of using the APTS market packages to public transportation agencies are forecast to include reduced labor costs, more productive use of vehicles and operators, more efficient passenger revenue collection, increased transit demand, more reliable and dependable service, increased system safety, and better short-term and long-range service planning. To the passenger, such improvements may reduce transit-related travel times (including waiting times and access and egress times), as well as improve other service attributes, such as convenience, reliability, and security. Features such as traveler access to information while en-route and in-vehicle security cameras to record "Mayday" events are all possible if the benefits outweigh the costs. The issue of privacy must be addressed if cameras were to be put on transit vehicles, however most users would welcome their presence for the sense of security they would convey.

Given this flexibility in interface specifications, the costs to implement these APTS-related market packages depend on the specific technologies (including hardware, software, and communications) chosen for local deployment. An initial cost analysis indicates that the costs per vehicle for AVI, automated fare processing, and security features may be as much as $6000/vehicle to start, with prices coming down as the volume of sales increases. Operations and maintenance costs per vehicle, including all of the APTS features using CDPD's current rates,are estimated at about $2000/vehicle per year with about one-half of this cost for the AVI function. Costs would also depend on the current level of deployment of many of these features at each local agency, given that many agencies have installed and operated similar systems in the recent past. Market packages can be introduced incrementally to support the needs of the user. Deployment is expected to be as high as 80% for some features in urban areas within 20 years. For this reason, significant market penetration of these packages may be achieved with early funding for development and deployment.

WESTINGHOUSE

Deployment-Oriented Specifics: Passenger operations are contained in System #4 (Transit System - see figure 21) and System #5 (PPT and RS System - see figure 22). These systems also interface with System #6 (Public Travel Services System) for some customer contact. The ITS enhancements to Systems # 4 and 5 consume about 1% of the total ITS cost. See figure 8 on page 50. The enhanced access to mass transit and the increased priority given to buses (via flyovers and preemption) increases its use by 33%, as shown in figure 9. This should substantially enhance the efficiency of transit operations. The increase occurs because of better travel planning data via kiosks, transit stop message signs, and the Transportation Services Center contained in the Public Travel Services System (System #6); better access to transit stops via PPT, ride sharing, and Park 'n Ride lots; increased availability and reliability of transit service due to better dispatch and more accurate vehicle location; and travel demand management policies Our architecture will truly succeed in bringing people to transit!

Standards/Compatibility: The Westinghouse architecture will not disenfranchise any passenger system operators - no mandate is embodied that precludes any existing service, equipment, or standard. The operators will be able to provide services in proportion to the investment made.

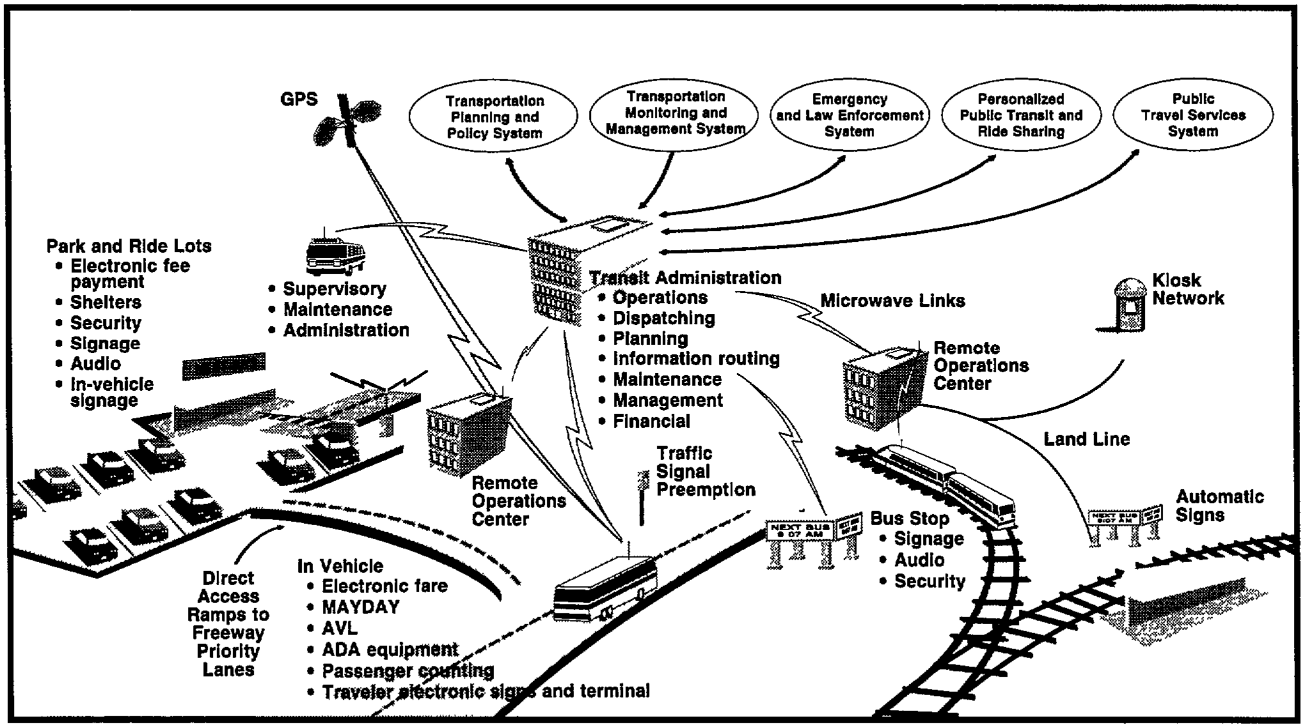


Figure 21. The Transit System (System 4) is structured to bring people to transit, and our urban deployment indicates that it succeeds.

Generally, the investment will be returned many times over, in terms of increased customer satisfaction and higher levels of service.

Our architecture has identified a range of passenger-service media to provide this higher level of service - pre-trip planning, enroute status, kiosks, and the like. These are already leading to the need for new standards.

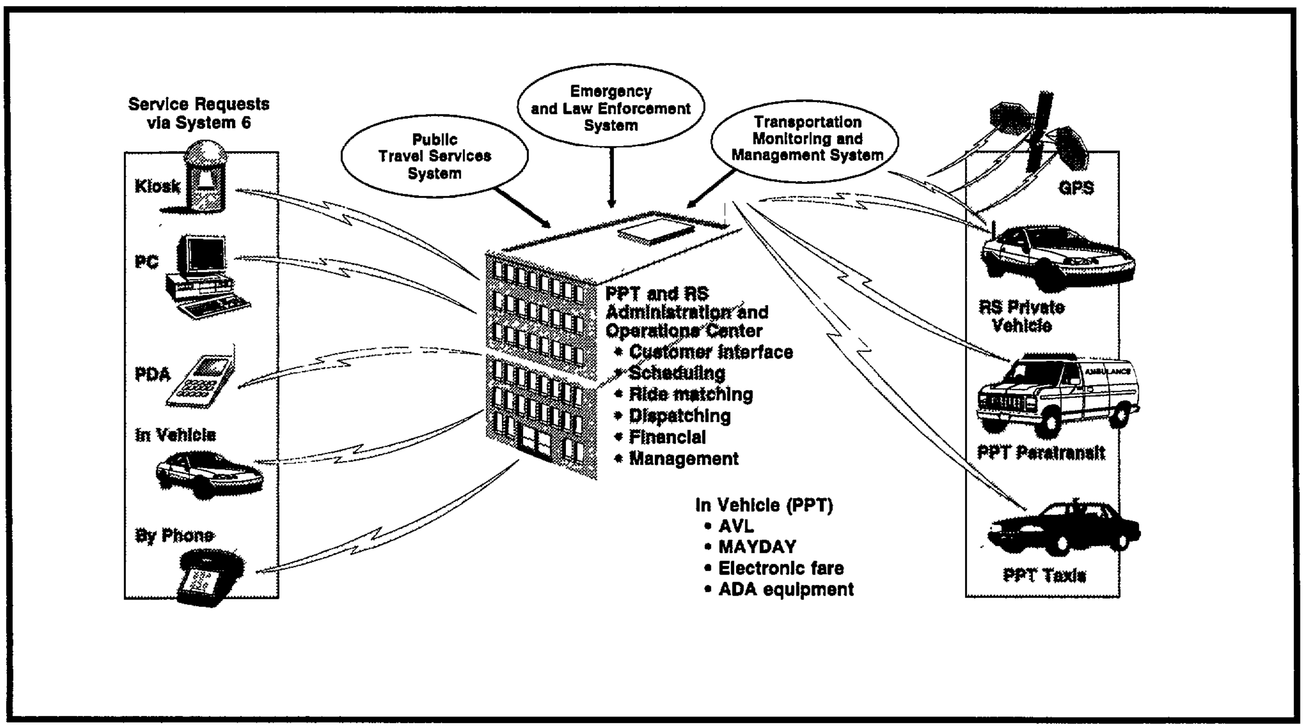


Figure 22. The PPT & RS System (System 5) is designed to mesh closely with the Transit and Public Travel Services Systems.

Also, one of the first new "ITS Standards" is for in-vehicle communications. These standards are needed to protect investments in vehicle equipment from "instant obsolescence" due to proprietary content, and to maximize the supplier base for equipment. The architecture encourages this.

Operations and Maintenance: The architecture explicitly provides structures to minimize O&M costs. These costs are contained via warranties, simple off-the-shelf replacement repairs, and automated diagnostic capabilities. Since the architecture system is structured to parallel existing transit systems, the O&M roles and procedures are essentially unchanged with respect to centers and vehicles. New communications and processing systems will require small additional amounts of O&M, and the **O&M** of the kiosk network may be relatively new to some system operators. This is an opportunity for a public/private partnership.

System reliability is enhanced by new on-board performance monitoring subsystems. They will prove to be self-financing by identifying trouble before it leads to the need for more expensive repair or replacement - and unnecessary ridership delays.

PRODUCT AND SERVICE PROVIDERS

HUGHES

VEHICLE MANUFACTURERS

Vehicle manufacturers and their electronics parts suppliers have opportunities for large scale production of in-vehicle equipment. Aftermarket suppliers can react to the market faster than the automotive manufacturers. A new approach is being used with the Oldsmobile Guidestar Route Guidance Computer which was designed to Oldsmobile requirements by Zexel, and is being built by a parts supplier and installed at the Oldsmobile dealerships.

COMMUNICATIONS SUPPLIERS

The Hughes Team Architecture makes extensive use of broadband landlines to meet the demand of traffic management agencies for remote CCTV surveillance of the freeways and main arterials. Satellite communications are used to provide CCTV surveillance in areas where wideband landlines are not available and where surveillance is needed only temporarily.

Cellular phones are currently used to make MAYDAY calls but the Architecture specifies a MAYDAY call which is automatically dialed if an accident occurs and the driver has not made the call. Longer range cellular phones are used with Low- and Medium-Earth Orbit satellite systems to make MAYDAY available in every part of the country. These satellite-based phones are compatible with conventional land-based phones.

The Architecture accommodates both Cellular Digital Packet Data (CDPD) and Personal Communications Systems since the virtual beacon uses standard public communication services.

The Architecture's tag/beacon communication is an outgrowth of the "open-road" electronic toll collection technology. The tags are low-priced, mass-produced and will become standard equipment on all new vehicles. The beacons are similar to a Personal Computer with a low-cost short-range radio.

INFORMATION SUPPLIERS

Route selection and guidance databases are required by the Route Guidance Computer, and are currently being created. Standards are being developed. Constant maintenance of these databases is a requirement. Rental car agencies are the first customers.

Maintaining the databases in vehicles requires that the supplier establish a distribution network or a subscription service to update databases in the vehicles. There are a number of approaches, varying from commercial outlets (e.g., gasoline stations) to mailing periodical updates to broadcasting updates covering the preceding 12 months.

Real-time traffic information generated by Traffic Management Centers and real-time transit schedule information generated by Transit Management Centers are made available to radio/TV stations, commercial vehicle and emergency vehicle dispatchers, and to providers of pre-trip planning services. Pre-trip planning services are provided via interactive TV to travelers at home, at the office, or at public kiosks.

TECHNOLOGY SUPPLIERS

The Architecture benefits from breakthroughs in vehicle radio receivers. Advanced digital technology is being applied to the design of a single receiver with multiple channels which can simultaneously receive AM, PM, GPS, cellular phone, tag/beacon, and traffic broadcast (possibly on a sideband).

Vehicle detection technology replaces the traditional loop detector with new technologies, such as radar and video image processing, which do not require installation in the road.

Software technology will develop advanced congestion prediction systems to exploit the extensive traffic data provided by the Architecture. An adaptive closed loop signal control system is based upon the data provided by arterial beacons which provide platoon tracking data.

EQUIPMENT SUPPLIERS

The largest market for infrastructure equipment is for beacons. The beacon market is very similar to the current market for traffic controllers.

The Traffic Management Centers are the market for specialized computer equipment, such as Geographic Information Systems (GIS), expert systems, traffic congestion analysis and prediction systems, and large-scale displays.

SYSTEM INTEGRATOR/CONSULTANT

The tendency is for the traditional separate procurement for consultant, system integrator and contractors to evolve into a single design/build procurement. This leads to partnerships between the traditional design consultants, the technology suppliers, and system integrators.

CONSTRUCTION

Construction firms team with technology suppliers and system integrators in order to be able to bid on the construction of new roads. This is already happening in the toll road industry. Long-term build/operate toll road franchises are being awarded to these teams.

BUSINESSES SERVING PEOPLE ON THE MOVE

The Hughes Team Architecture accommodates the TMC franchising of beacon operation and maintenance to private firms who would sell yellow-pages advertising to businesses located at freeway off ramps. The information provided by the beacon could be dynamic, such as motel vacancy and room rate. The beacon would transmit the information only upon request of the passing driver. A precedent is the highway "clean-up" advertisement signs.

The pre-trip planning service provider offers new and innovative services. For example, a basic service would be to provide the user with the latest time he can leave to catch a particular airline flight.

Package Availability and Preliminary Cost

The following chart provides preliminary availability and costs for the packages discussed above. The pair of numbers in each column are for initial introduction and for 5% penetration.

The tag costs are for a basic toll collection model and do not include options for displays, voice output and keypad; the tag will eventually be integrated into the vehicle. The beacon cost includes $2000 to $3000 for freeway installation. The virtual beacon cost assumes the vehicle has a cellular phone. Delay in availability of the virtual beacon and superprobe is due to product development. Route guidance has just been introduced in the U.S. Interactive TV is being introduced this year, and will eventually be built into every TV. Collision warning is on the road now, but more general availability as an OEM system is shown to be later.

PACKAGE	AVAILABILITY	COST $
tag	1992 - 2001	40 - 25
beacon (installed)	1992 - 2001	4000 - 3000
virtual beacon	1996 - 2003	400 - 200
superprobe	1998 - 2004	350 - 100
route guidance	1994 - 1999	2000 - 500
interactive TV	1993 - 2000	100 - 0
collision warning	1998 - 2001	1500 - 500
collision avoidance	2005 - 2010	1000 - 750

LORAL

The Loral Architecture emphasizes private sector leadership in providing products and services to deliver ITS User Services.

In the five year time-frame, Independent Service Providers (ISP) will realize initial commercial ITS opportunities. Autonomous route guidance systems, non personalized traffic advisory systems, automatic vehicle location and cellular voice and data systems will be early winners. Larger cities and municipalities will expand their traffic surveillance and management capabilities--system integrators will provide solutions through government procurements.

In the ten year timeframe, services like multimodal trip planning, in-vehicle yellow pages, urban automated parking facilities and electronic transaction will be widely available. Industry and market standards will be in place, encouraging manufacturers to design and build standard compliant systems.

In the twenty year timeframe, deployment of all ITS User Services is envisioned. ITS service providers will be fully integrated with non-ITS services, supporting the combination of travel with other activities. Private companies and public agencies will have a full set of tools to coordinate services to customers, like real-time route guidance, signal control priorities, and automated licensing and registration for commercial and passenger vehicles.

MARKET CONSIDERATIONS

The market for both transportation infrastructure and in-vehicle products and services over the next 20 years is immense. Over 75 major metropolitan U.S. areas anticipate either developing or greatly enhancing their transportation infrastructure in this decade--a potential $1.5 billion market for system integrators, consultants and suppliers. The in-vehicle market for ITS products will realize a 3% penetration in five years growing to over 50% in twenty years. Depending on specific configurations and functionality, in-vehicle unit prices will range from a few dollars for electronic tag technology to a few hundred dollars for route guidance systems. Annual U.S. vehicle sales of 12-15 million will provide a multi-billion dollar ITS market for products and services.

OPEN ARCHITECTURE

Use of open interfaces is a priority of the Loral Team Architecture. All subsystems will support a range of existing or anticipated product offerings from product and service providers. The Loral team has identified the traveler to infrastructure interface as an area for early, detailed open standardization. The Loral Team is working directly with the Society of Automotive Engineers (SAE) to make recommendations on an open standard that will spur product development for this key ITS product market.

PUBLIC/PRIVATE PARTNERSHIPS

The Loral Architecture enables private and public entities to collaborate in providing ITS services. In the next five years, many projects will remain a mixture of public and private funding and responsibilities. Operational tests, studies and research help industry and government reduce risk and better understand the institutional, technical and market acceptance for ITS products and services.

Over the entire twenty year time frame, we envision user demand for many value-add products and services will be met by private industry. Our Independent Service Provider subsystem encourages private firms to meet this demand directly. However, our architecture continues to allow ISPs to exchange data with public entities, if desired. This opens additional marketing channels for introducing new products and services in regions where the public sector has advanced transportation management capabilities which complement the commercialized product or service.

ROCKWELL

Through service offerings and product lines, service providers and product vendors enable consumers to access ITS applications, and they assist operations staff in managing a deployed ITS. The product vendor and service providers can be viewed along four functional areas that are explicitly addressed within the Rockwell architecture: computing, communications, devices and location determination. One common theme expressed within this perspective is the reliance on existing and emerging technologies to mitigate risk and to realize early benefits. Furthermore, this is accomplished through an architecture definition that creates a unique balance between in-vehicle equipment and infrastructure private service providers, all within an open framework that encourages competition.

A few examples illustrate the above notions. The ATIS market packages developed by the team, offer both “interactive ATIS with in-vehicle GIS and GPS” along with “interactive ATIS with infrastructure route planning”. The former package creates ample opportunities for vehicle electronics, processor, display and even satellite manufacturers. The latter package offers a unique set of opportunities for value added resellers who tend to be entrepreneurial firms. Both packages are to be supported to varying degrees by wireless communication providers and consequently by communication product manufactures (modems, radios, base station hardware, etc.). These two packages are examples. Others offer multiple opportunities for software developers (portable and in-vehicle computing, analysis of raw information in desktop and network environments, routing algorithms, etc.) A third key market package is Mayday. The provision of this basic and essentially inexpensive service, supported by a simple panic type device, encourages infrastructure and communication providers to leverage their existing assets to offer inexpensive but reliable location determination techniques. Networks of FM stations, cellular and other radio networks are one possible means to create the required location determination.

The Rockwell Team architecture also facilitates market entry and market development through its modular packages. These packages can be developed with varying degrees of functionality and technical sophistication. The architecture inherently supports a very diverse market of products and services. This diversity means that small and large fiis may enter the market at different levels with considerable ease.

The Rockwell Team architecture does not specify or bind users to any one specific implementation approach. Its unbiased openness, should in fact encourage vendors to enter the ITS market as they see opportunities open up for products and services. As is typical, the market may evolve through a natural process that is led in part by the availability and capability of hardware. That is, hardware vendors will influence the requirements analyses of implementors, thereby dictating the market through technology availability. Software and other applications could lag the market development slightly.

For a number of services, it is expected that the private sector will be responsible for product and service development and provision. This is most notable for the vehicle-based services, such as commercial vehicle tracking, traveler information systems, and in-vehicle safety devices. These markets are likely to have considerable opportunities for low risk investment. In other cases, the private sector may also work with the public sector in providing services, as with traveler information services or personal, or vehicle-based Mayday. However, in some cases, custom hardware and software for novel, risky projects may require considerable financial investment with unknown return, at which point collaboration between the public and the private sector could encourage prototype development. Strategic alliances between private sector enterprises could also be formed for the same reason.

From a standards viewpoint, the architecture minimizes the requirements for standards. Where it does call out that standards be established, it is done to support national interoperability. By not being over specified, the Rockwell Team architecture conceivably supports the creation of a multitude of new product ideas and implementation approaches. In all cases, if standards are to be developed, they should be developed within existing standards setting bodies, such as SAE, ISO, NEMA, and ITA. Services that require national interoperability to be viable, will require standards at the applications, transport, and physical layers of the International Standards Organization (ISO) model. Examples include short range communications interfaces for toll collection, credential checking for commercial vehicle operations, and personal or vehicle-based Mayday. Other interfaces will only require standards at the applications layer to facilitate access to database information. Standards are recommended for interagency or interjurisdictional communications, so as to mitigate issues, as the need for information sharing grows in the future. These would include interfaces between the traffic management system and traveler information providers, or between the traffic management system and emergency response agencies. The architecture however, discourages standards for product design. Common user interfaces are recommended. Finally, the architecture does not specify standards for communication and interfaces that are maintained within a single organization, such as wireline communications between traffic managers and roadside devices, or wireless communications between fleet vehicles and fleet headquarters, or between emergency management and emergency vehicles.

The basic idea is that ITS markets will be accepted and grow based on market forces. Public/private partnerships will help get it started, however the real growth will occur only when entrepreneurial firms see a market and then commit themselves to fulfilling its needs. The Rockwell Team's architecture encourages their commitment by being open and not overly prescriptive. It recommends interface standards only where national interoperability is concerned. This allows a wide variety of communications providers, such as RAM, ARDIS, SMR, ESMR, CDPD, etc. to find a niche for their services. This approach also supports the infrastructure implementors. It allows local jurisdictions to design systems based on their requirements and their perception of needs. It does not embed policy. It does not force jurisdictions to adopt a philosophy because that philosophy is embedded in the architecture design.

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Deployment-Oriented Specifics: The product and service providers are interested in all of the ITS systems to some extent, since they will be called upon to install most of the ITS. However, their primary focus will be on System #6 (Public Travel Services System - see figure 23) and System #7 (Personal Travel Support System - see figure 10 on page 60). System #6 provides a prime opportunity to provide information services to paying consumers via the Traveller Service Center (TSC), while System #7 provides the chance to sell equipment to a huge customer base. See figure 11 on page 60 for a look at the vehicle equipment. As shown in figure 8 on page 50, the cost of these two systems is almost 90% of the total ITS cost. For additional pricing details, see the discussion under the consumer stakeholders above.

Market: Ours is a flexible architecture. It accommodates market size (and potential market share) in many ways. For example, the four sets of in-vehicle equipment (Basic, Standard, Premium, and Advanced) will provide a wide market for the low-end, inexpensive subsystems, but more

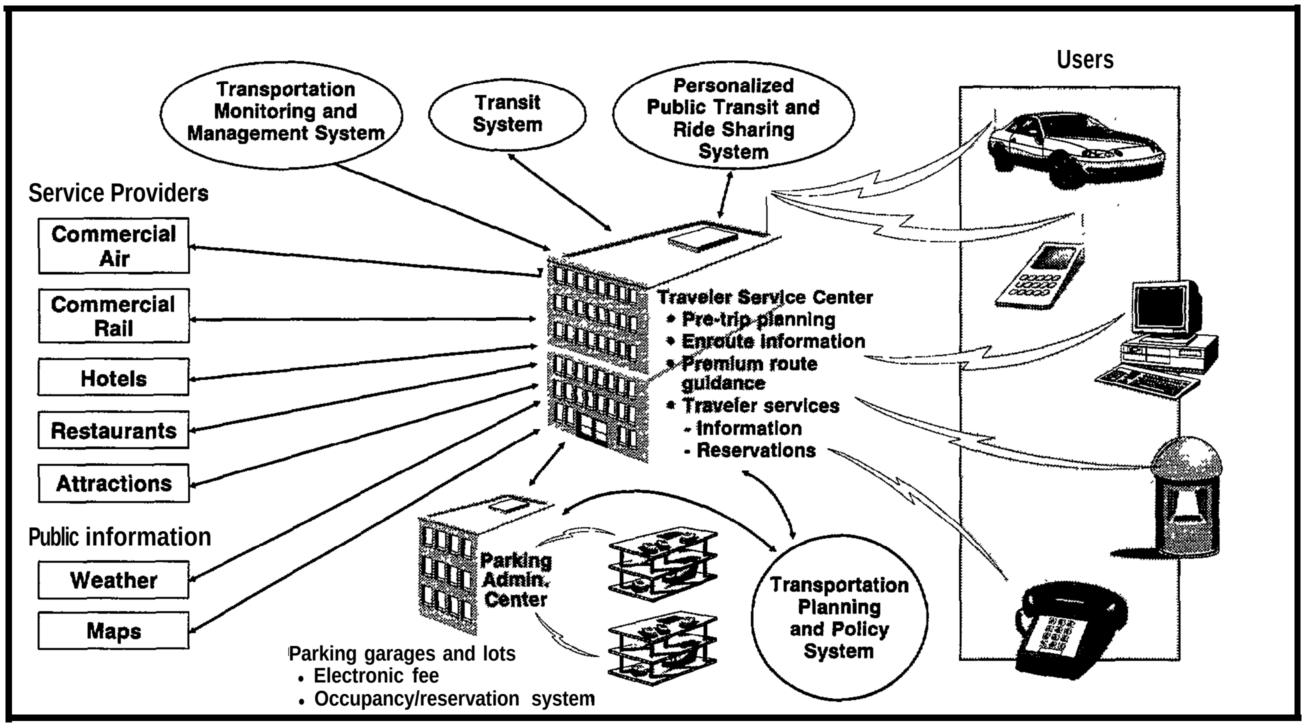

Figure 23. The Public Travel Services System (System 6) provides a Travel Service Center to disseminate all forms of travel information.

competitive opportunities for the more expensive (and potentially subscriber supported) high-end subsystems. Home computers and PDAs provide additional market potential. These products are synergistic with the provision of services via the TSC in System #6, since the premium equipment uses the services of the TSC, including trip planning and centralized route guidance. This enhances the attractiveness of the market.

Our evolutionary deployment projections track the above analogy. As system functionality and user acceptance grow, so too will the business opportunities for the product and service sectors. Almost 90% of the deployment is a consumer driven process, and this obviously affords the product and service providers a golden opportunity. There will be more than adequate room for major service organizations and OEMs, as well as opportunities for small business.

Partnerships: Following the trend in the US society today, ITS will provide - and our architecture encourages - entrepreneurship in identifying new travel and management services and entering into public-private partnership to provide them. As noted above, ITS is single-handedly the best opportunity for public-private, interjurisdictional, and inter-agency cooperation. All of the systems are explicitly designed with this in mind. Smart cards could be issued via a public/private entity. The architecture provides the opportunity to broadcast government supplied data via FM sidebands, with value added to the extent desired. Traveler service and transit kiosk networks provide an opportunity for partnerships between the Transit System and private entrepreneurs. The EMCAC could be a public/private enterprise. We believe that government, business, and industry working together provides superior products and services, increased confidence by the using public, and considerably better economic opportunities for all concerned.

Standards/Compatibility: This is the real ground-breaking area of ITS - products such as in-vehicle, in-home/office, and PDA subsystems. There are no standards to speak of. Certainly many interface standards must be accommodated, but this whole area is ripe for development. Our architecture framework provides for an orderly, cooperative development of these new standards and protocols. This is an ideal opportunity for the private sector to cooperate in the self-imposed production of standards to ensure nationwide compatibility of basic ITS services. At the same time, the architecture affords the flexibility for value-added enhancements to make individual companies' products competitive.